COMMISSION DE LA CARTE GÉOLOGIQUE DU MONDE
COMMISSION FOR THE GEOLOGICAL MAP OF THE WORLD

BULLETIN 55

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COMMISSION FOR THE GEOLOGICAL MAP OF THE WORLD (CGMW)

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(AS AT AUGUST 2008)

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COMMISSION DE LA CARTE GEOLOGIQUE DU MONDE (CCGM)
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(AS AT AUGUST 2008)

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EDITORIAL

The world of mapping sciences is ever-changing, and so does CGMW. Global environmental and economic issues go with an increasing need for small scale maps, among which geological maps are important. The 'International Year of Planet Earth' is a recent example which illustrates the necessity to look at the planet as a whole.

CGMW is currently having plenty of small-scale maps projects, the hallmark of which is the publication of the new edition of the Geological map of the World at scale 1:50 M. The other publications include a selection of maps ranging from a map of the Atlantic Ocean up to a World magnetic anomaly map, or others resulting from long term projects such as the Tectonic map of Africa and the geological maps of Asia and the Middle East.

A witness of this evolution is the project “OneGeology” which aims to create dynamic geological map data of the world available via the web, at the scale of 1:1.000.000. The project was born at the CGMW General assembly of 2006. This project allows access to geological information for everyone. Participating nations and geological surveys to the initiative have helped expanding it rapidly.

Far from being a competitor for CGMW products, this type of projects encourages our initiative to move toward geo-coded digital maps, and gives CGMW a role in the scientific validation of the geological maps. Hence, CGMW is an official partner of One Geology since April 2009.

Finally, the concepts of geological maps also evolve together with technology and an increasing growth of exchange of information from diverse sources. The new map projects bring about, for example, questions on how subsurface information such as buried structures or basins can be indicated on geologic and tectonic maps.

Hence, the *sensu stricto* concept of geological map representing only the age of the formations moves gradually toward a geological and structural map which, by underlining the main tectonic units, expresses the 3D geometry of the formations.

EDITORIAL

Le monde de la cartographie change, et la CCGM s’adapte à ses évolutions. La mondialisation des grands problèmes environnementaux et économiques va de pair avec un besoin de cartes à petite échelle, dont les cartes géologiques font partie. L’Année Internationale de la Planète Terre est un exemple récent qui en illustre les enjeux.

La CCGM possède actuellement une foison de projets de cartes à petite échelle, dont le produit phare est la publication de la toute nouvelle édition de la Carte géologique du Monde à l’échelle du 1:50 M. Les autres publications incluent des cartes variées allant d'une carte de l'océan Atlantique à une carte mondiale des anomalies magnétiques, ou d'autres qui resultent de projets de longue durée comme la Carte tectonique de l'Afrique, les cartes géologiques de l'Asie et du Moyen Orient.

Témoin de cette évolution, le projet international «OneGeology» qui vise à rassembler dynamiquement à l’échelle mondiale les cartes géologiques numériques fournies par chaque pays à l’échelle nationale, est dédié aux cartes à l’échelle du 1:1M. Ce projet, lancé lors de l’Assemblée générale de 2006 reçoit le soutien des pays participants et de leur service géologique, qui a permis de le faire progresser rapidement.

Loin d’être une concurrence à nos produits cartographiques, ce type de projet nous conforte dans notre objectif de produire des cartes numériques géoréférencées, accessibles à tous, et confère à la CCGM un rôle de validation scientifique des cartes géologiques. La CCGM est donc offficiellement depuis avril 2009 partenaire de OneGeology.

Enfin, les concepts de carte géologique évoluent en même temps que la technologie et l’accumulation d’informations. Les nouveaux projets de cartes amènent, para exemple, une réflexion sur la représentation des données de sub-surface, comme les bassins sédimentaires cachés sous des sédiments à terre ou en mer.

Ainsi, le concept même de carte géologique *sensu stricto* qui ne représenterait que l’âge des formations, s’efface t’il devant celui d’une carte géologique et structurale qui, en soulignant les grandes unités tectoniques, rend compte de la géométrie en volume des formations.

Manuel Pubellier
Secretary General Elect

Paris, 30 November 2009

In memoriam: Jacques Ségoufin (1938-2008)

Notre collègue Jacques Ségoufin nous a quitté le 9 septembre 2008, il venait d'avoir 70 ans.

Jacques avait pris sa retraite en 2004 après une longue carrière débutée dans les Terres Australes et en Antarctique où il avait séjourné à plusieurs reprises. Il avait ensuite rejoint le laboratoire de Géophysique marine de l'Institut de Physique du Globe de Paris. Il a alors participé, organisé et animé de nombreuses campagnes océanographiques, notamment dans l'océan Indien dont il était un spécialiste mondialement connu et sur lequel il a poursuivi ses travaux jusqu'à ses derniers mois de vie.

Après son départ en retraite, il avait en effet poursuivi ses activités dans le cadre de la CCGM, dont il a été le Secrétaire Général de la Subcommission des Cartes des fonds sousmarins entre 1985 et 2004. Ses dernières contributions à la Commission furent la feuille physiographique de la Carte structurale de l'océan Indien publiée en 2004, puis l'encart physiographique de la Carte structurale de l'Atlantique Nord parue en 2008, et finalement la feuille Physiographique de la 3ème édition de la Carte géologique du Monde, publiée en novembre 2009. Jacques avait une personnalité attachante et entière. Il était très attentif aux autres ainsi que le attestaient ses engagements de soutien scolaire et d'animations pédagogiques dans les écoles. Il fut une collaborateur discret mais efficace de la Commission où il était particulièrement apprécié.

Our colleague Jacques Ségoufin died on September 9, 2008 at the age of 70.

Jacques retired in 2004 after a long career that begun in the Southern lands and Antartica, where he sojourned several times. Thereafter, he joined the laboratory of marine geology of the Institut de Physique du Globe of Paris. During his service, he organised and conducted a number of oceanographic field missions, in particular in the Indian Ocean, a region of which he was a world renown expert and that he continued to study until the very end of his life.

Between 1985 and 2004, he occupied the post of Secretary General of the CGMW Subcommission for Seafloor Maps. His last contributions to the Commission were: the physiographic sheet of the Structural Map of the Indian Ocean published in 2004, followed by the physiographic inset of the Structural Map of the North Atlantic released in 2008 and finally the Physiography sheet of the Geological Map of the World issued in November 2009. During the last years at the Institut de Physique du Globe de Paris, he devoted part of his time to teaching and coordinating field work on geophysics and marine seismics. Jacques had a charming and resolute personality. He was concerned about others as proved his voluntary tutorial and educational work in several schools. Jacques was a discreet and efficient collaborator of the Commission where he was particularly appreciated.

In memoriam: Renato Funiciello (1939-2009)

On August 14, 2009 Prof. Renato Funiciello passed away at the age of 70. Renato was an eclectic scientist who contributed immensely to the Italian and the International scientific community. He served many years as full professor of structural geology at University of Roma 3, where he strongly promoted the Laboratory of Experimental Tectonics activities, but his interests spanned the entire field of geology.

He loved volcanoes and researched many aspects, ranging from hazards to tuffs as building stones. One of his first scientific projects was the study of lunar samples from the Apollo missions to the Earth's Moon.

He was vice-president of the Istituto Nazionale di Geofisica, and prompted the Italian participation in studies of Antarctica. In the 1980's and 1990's Renato promoted and participated in studies of volcanic geothermal areas of central Italy, co-writing some of the most important summaries of Italian volcanism. Many volcanologists will remember him leading the 1985 IAVCEI Explosive Volcanism group field excursion through the Alban Hills. During the last several decades he realized the importance of urban geology, developing a multidisciplinary approach for city planning and hazard studies. He loved Roma and its volcanoes, the Colli Albani and the Sabatini volcanoes —so much so that he promoted and coordinated two very complete monographs on the geology of Rome and the geological maps of the entire Roma Municipality and of the Colli Albani volcano. Renato hasn't seen his last work to be published, which is the forthcoming monograph on the Colli Albani (Alban Hills). The new book also contains descriptions of one of his most exciting discoveries, i.e. the activity of the Albano maar during pre-historical and early Roman times. He was friend and co-worker of several french scientists including, JP Cadet, C. Laj, C. Kissel, L. Jolivet, S. Lallemand. He contributed to the Commission's Geodynamic Map of the Mediterranean and adjacent area. Anyone who met him knew of his enthusiasm and great humanity. He was a real optimist, who devoted a lot to the students, being a mentor for many of them and creating a new Geology department within the University of Rome.

He also believed that geology could actively contribute to a better world, a very sound message for the future

RESOLUTIONS OF THE CGMW GENERAL ASSEMBLY

OSLO – 33TH IGC

RÉSOLUTIONS DE L'ASSEMBLÉE GENERALE DE LA CCGM

OSLO – 33E CGI

August 9, 2008 **9 août 2008**

The Commission

1. **thanks** the Organizing Committee of the 33rd IGC for its support for the preparation of the present General Assembly and the Secretary General of the 33rd IGC for providing the facilities for the holding of this General Assembly in Oslo, and
2. **approves** the creation of a new Thematic Subcommission devoted to Geophysical maps, and
3. **acknowledges** the resignations of Dr. G. Grikurov and Dr. M. Munschy from their positions respectively as Vice-President for Antarctica and Secretary General of the Subcommission for Seafloor Maps, and
4. **endorses** the appointment of the following new Bureau Members:
   - Dr. Abdollah Saidi, General Director of the National Geosciences Database of Iran, as Secretary General of the Subcommission for the Middle East,
   - Dr. Yves Lagabrielle, CNRS (French National Council for Scientific Research) at Géosciences Montpellier, as Secretary General of the Subcommission for Seafloor Maps,
   - Prof. Mioara Mandea, GFZ (Deutsches GeoForschungsZentrum, Potsdam, Germany) as President of the Subcommission for Geophysical Maps,
   - Dr. Manuel Pubellier, CNRS-Ecole Normale Supérieure, Paris, as CGMW Secretary General elect,
   - Dr Philippe Rossi, BRGM, as CGMW President elect, and
5. **extends** its most sincere thanks to the BRGM (French Geological Survey) for its continuous and generous support, and more particularly for renewing the nomination in 2007 and 2008 of a member of its staff to fulfill the duties of Secretary General of CGMW, and
6. **expresses** its appreciation to the Geological Survey of Norway (NGU) and the National Oceanography Centre of Southampton (NOCS) for their scientific input and generous sponsoring for the preparation and publication of the CGMW maps published on the occasion of the 33 IGC, and
7. **thanks** the Geological Surveys who besides their membership fees provide also to the Commission support especially as concerns the contribution of their geologists, researchers, engineers and technicians who had been working in regional and/or continental and/or oceanic syntheses to compile CGMW maps and,
8. **warmly thanks** IUGS and EPISODES's Chief Editor for contributing to the promotion and visibility of CGMW publications, and
9. **gives** its warmest thanks to UNESCO for its support to the preparation and publication of CGMW maps, and **thanks** IUGS for its annual subsidy and support, and

CONTINENTAL SUBCOMMISSIONS

SUBCOMMISSION FOR EUROPE

10. **congratulate**s Dr. Kristine Asch and Alexander Müller of the German Federal Institute for Geosciences and Natural Resources (BGR) on the rapid progress and excellent work to produce the reprint of the *International Quaternary Map of Europe 1:2.5 M* at the reduced scale of 1:5 M as a special edition of the International Year of Planet Earth (IYPE), as a supplement to the *International Hydrogeological Map of Europe*, reduced similarly. Both maps are also available via the Internet as a Web Map Service (WMS), and
11. **thanks** the TRACE project in their support of the above, and
12. **encourages** BGR to build a GIS on the Quaternary with a modern and reviewed legend/structure, and

La Commission

1. **remercie** le Comité d'organisation du 33e CGI pour son aide à la préparation de la présente Assemblée générale et le Secrétaire Général du 33e CGI pour la mise à disposition des facilités permettant la tenue de cette réunion à Oslo, et
2. **approuve** la création d'une nouvelle Sous-commission en charge des Cartes géophysiques, et
3. **prend acte** de la démission du Dr G.Grikurov et du Dr M. Munschy de leur position respective de Vice-Président pour l'Antarctique et de Secrétaire Général de la Sous-commission des Cartes des fonds sous-marins, et
4. **avalise** la nomination des nouveaux membres du bureau suivants :
   - le Dr Abdollah Saidi, Directeur Général du Service de la base de données géosciences d'Iran, en tant que Secrétaire général de la Sous-commission du Moyen-Orient,
   - le Dr Yves Lagabrielle, Directeur de recherche au CNRS (Centre National de la Recherche Scientifique) à Géosciences Montpellier, comme Secrétaire général de la Sous-commission des Cartes des fonds sous-marins,
   - le Professeur Mioara Mandea, du GFZ (Deutsches GeoForschungsZentrum, Potsdam, Allemagne) comme Présidente de la Sous-commission des Cartes géophysiques,
   - le Dr Manuel Pubellier, CNRS, École Normale Supérieure, Paris, comme Secrétaire Général désigné de la CCGM,
   - le Dr Philippe Rossi, BRGM, comme Président désigné de la CCGM, et
5. **transmet** ses remerciements le plus sincères au BRGM (Bureau de Recherches Géologiques et Minières) pour son aide continue et généreuse, et plus particulièrement pour le renouvellement de la mise à disposition en 2007 et 2008 d'un membre de son personnel pour assurer le Secrétariat général de la CCGM, et
6. **exprime** sa gratitude au Service Géologique de la Norvège (NGU) et au Centre National d'Océanographie de Southampton (NOCS) pour leur apport scientifique et leur aide financière pour la préparation et la publication des cartes de la CCGM publiées à l'occasion du 33e CGI, et
7. **remercie** les Services Géologiques qui, en plus de leur cotisation, fournissent à la Commission leur aide, spécialement la contribution de leurs géologues, chercheurs, ingénieurs et techniciens qui ont travaillé aux synthèses régionales et/ou continentales et/ou océaniques pour compiler les cartes de la CCGM, et
8. **remercie** chaleureusement l'IUGS et l'éditeur en chef d'EPISODES pour leur contribution à la promotion et à la visibilité des publications de la CCGM, et
9. **transmet** ses profonds remerciements à l'UNESCO pour son aide à la préparation et à la publication des cartes de la CCGM et remercie l'IUGS pour sa subvention annuelle, et

SOUS COMMISSIONS CONTINENTALES

SOUS-COMMISSION POUR L'EUROPE

10. **félicite** le Dr Kristine Asch et Alexandre Müller de l'Institut Fédéral Allemand pour les Géosciences et les Ressources Naturelles (BGR) pour leur rapidité et leur excellent travail pour la réimpression de la *Carte Internationale du Quaternaire de l'Europe au 1/2,5 M*, à l'échelle réduite du 1/5 M, au titre d'édition spéciale pour l'Année Internationale de la Planète Terre (IYPE) et comme complément à la *Carte Hydrologique Internationale de l'Europe* publiée avec la même échelle de réduction. Les deux cartes sont aussi accessibles via internet en tant que Web Map Service (WMS), et
11. **remercie** le projet TRACE pour son aide pour la réalisation du projet précédent, et
12. **encourage** le BGR à construire un GIS sur le Quaternaire avec une **structure**/légende moderne et révisée, et

13. **congratulates** Dr. Kristine Asch on the printing of a new version of the 1:5 M *International Geological Map of Europe and Adjacent Areas at 1:5 M* reduced to the scale 1:10 M for distribution in public and for education, and

14. **appreciates** the progress of the DIMAS working group – K. Asch (Chair), J. Broome, I. Jackson, D. Janjou, M. Pubellier, D. Soller, R. Tomas, K. Wakita & J. Wang – on developing a metadata system, and developing Guidelines for Geological maps, geographic information systems and supports the publication by print of a booklet and a web version as input e.g. to GeoSciML and thus to OneGeology and the new EU INSPIRE Directive, and

SUBCOMMISSION FOR AFRICA

15. **acknowledges** the progress achieved in the compilation of the onshore and offshore sedimentary basins of the *Tectonic Map of Africa at 1:5 M scale* whose complete (basement & basins) draft will be presented at the next Colloquium on African Geology to be held in Hammamet in early November 2008, and

16. **thanks** the Company TOTAL for funding a geologist for 18 months to gather and synthesize the geology of onshore and offshore basins for the realization of the *Tectonic Map of Africa*, and

17. **encourages** further progress of the *Seismotectonic Map of Africa at the 1:5 M scale* with continued support by the Council for Geoscience (South Africa) in order to complete the project by 2009, and

SUBCOMMISSION FOR NORTH AND CENTRAL AMERICA

18. **acknowledges** the progress achieved so far by the US Geological Survey in the digitization of the *Geological Map of North America at the 1:5 M scale*, and

19. **encourages** the realization of a reduced scale version of the above-mentioned map, and

SUBCOMMISSION FOR SOUTH AMERICA

20. **expresses** its satisfaction with the efforts made by Profs. U. Cordani and V. Ramos in the preparation of the first complete continental draft of the *Tectonic Map of South America at the scale of 1:5 M,* using GIS technology, with the support of the Mining Survey of Argentina (SEGEMAR) and the Geological Survey of Brazil (CPRM), to be published in 2009, and

21. **expresses** its satisfaction with the preparation of the first draft of the sheet NA.22 of the *Geological and Mineral Resources Map of South America project at 1:1 M scale, and related data bases (GIS-South America 1:1 M)*, prepared by the geological surveys of Brazil (CPRM) and France (BRGM), harmonizing trans-boundary geological and geophysical information, and

22. **expresses** its satisfaction with the preparation of the final draft of the sheet SH.21 of the *Geological and Mineral Resources Map of South America project at 1:1 M scale, and related data base (GIS-South America 1:1 M),* prepared by the geological surveys of Argentina (SEGEMAR), Brazil (CPRM) and Uruguay (DINAMIGE), harmonizing trans-boundary geological information, with the support of the Mercosul / Mercosur (*Southern Common Market*), and

23. **expresses** its interest in the preparation of a new version of the *Geological Map of South America at 1:5 M scale*, using GIS technology, under the aegis of CGMW, in conjunction with the Ibero-American Association of Geological and Mining Surveys (ASGMI), to be ready in 2010 as a final version, and

13. **félicite** le Dr Kristine Asch pour l'impression d'une nouvelle version de la *Carte géologique internationale de l'Europe et des régions voisines au 1/5 M* à l'échelle réduite du 1/10 M pour distribution dans le publique et pour l'enseignement, et

14. **apprécie** les progrès du groupe de travail DIMAS – K. Asch (Présidente), J. Broome, I. Jackson, D. Janjou, M. Pubellier, D. Soller, R. Tomas, K. Wakita et J. Wang – dans le développement d'un système de metadata et la proposition de directives pour les cartes géologiques, les systèmes d'information géographiques et soutien l'impression d'une brochure et la préparation d'une version électronique comme contribution à GeoSciML, ainsi qu'à OneGeology et à la nouvelle directive européenne INSPIRE, et

SOUS-COMMISSION POUR L'AFRIQUE

15. **prend acte** des progrès réalisés dans la compilation des bassins sédimentaires,à terre et en mer, de la *Carte tectonique de* **l'Afrique** *à l'échelle du 1/5 M* dont une maquette complète (socle et bassins) sera présentée au prochain Colloque sur la Géologie Africaine que aura lieu à Hammamet début novembre 2008, et

16. **remercie** la **compagnie** TOTAL pour le financement pour 18 mois d'un géologue pour rassembler et synthétiser la géologie de bassins, à terre et en mer, de la *Carte tectonique de l'Afrique*, et

17. **encourage** la compilation de la *Carte seismotectonique de l'Afrique au 1/5 M* avec le support du Council for Geoscience (Afrique du Sud) pour achèvement du projet en 2009, et

SOUS-COMMISSION POUR L'AMERIQUE DU NORD ET CENTRALE

18. **prend acte** des progrès realisés par l'US Geological Survey dans la digitalisation de la *Carte géologique de l'Amérique du Nord au 1/5 M*, et

19. **encourage** la réalisation d'une version à une échelle réduite de la carte sus-mentionnée, et

SOUS-COMMISSION POUR L'AMERIQUE DU SUD

20. **exprime** sa satisfaction pour les efforts réalisés par les Profs.U. Cordani et V. Ramos dans la préparation de la première ébauche complète de la *Carte tectonique de l'Amérique du Sud à l'échelle du 1/5 M*, en utilisant la technologie GIS, avec l'aide du Service géologique et minier de l'Argentine (SEGEMAR) et du Service géologique du Brésil (CPRM), pour publication en 2009, et

21. **exprime** sa satisfaction pour la préparation de la première maquette de la feuille NA.21 du projet de *Carte géologique et des ressources minérales d'Amérique du Sud au 1:1 M*, associée à la base de données correspondante (*GIS-Amérique du Sud au 1:1 M*), préparé par les Services géologiques du Brésil (CPRM) et de France (BRGM) avec harmonisation des informations géologiques et géophysiques transfrontalières, et

22. **exprime** sa satisfaction pour la préparation de la maquette finale de la feuille SH.21 du projet de *Carte géologique et des ressources minérales au 1:1 M*, associé à la base de données correspondante (*GIS –Amérique du Sud au 1:1 M*) préparée par les Services géologiques d'Argentine (SEGEMAR), du Brésil (CPRM) et de l'Uruguay (DINAMIGE), avec harmonisation des informations géologiques et géophysiques transfrontalières et le support du Mercosul/Mercosur (Marché commun de l'Amérique du Sud), et

23. **exprime** son intérêt dans la préparation d'une nouvelle version de la *Carte géologique d'Amérique du Sud au 1/5 M*, en utilisant la technologie GIS, sous les auspices de la CCGM, en liaison avec l'Association Ibéro-américaine des Services géologiques (ASGMI), dont la version finale serait achevée pour 2010, et

24. **appreciates** the progress achieved in the preparation of the *Geological Map of Patagonia at 1:1 M scale* by the Geological Surveys of Argentina (SEGEMAR) and Chile (SERNAGEOMIN) to be completed by 2009, and

SUBCOMMISSION FOR SOUTH AND EAST ASIA

25. **expresses** its deepest satisfaction with the preparation of a nearly complete draft of *the International Geological Map of Asia (IGMA)* at 1:5 M scale displayed at the China booth in Geoexpo 2008, and
26. **thanks** the China Geological Survey (CGS) for its full support to the realization of the IGMA project and the funding of the international meetings and workshops for this purpose, and
27. **expects** the Subcommission for Middle East will be able to provide as soon as possible the digital draft of the second edition of the *Geological Map of the Middle East at 1:5 M scale* in order to complete the southwestern part of IGMA, and
28. **asks** the Subcommissions responsible for the mapping of surrounding regions to provide digital information in order to complete the relevant areas of the map, and
29. **thanks** the international working group of IGMA 5000 for the proposal of compiling the following thematic maps on the basis of IGMA 5000: Resources Map of Asia (Hydrocarbon, metals, non-metal resources, etc.), Geological hazards Map of Asia, Phanerozoic Paleotectonic and Paleogeographic Maps of Major Tectonic Stages of Asia, Metamorphic Map of Asia, and the Magmatic Map of Asia
30. **expresses** to Acad. Ren Jishun, coordinator of the IGMA Map, its sincere wish for a prompt recovery and good health, and

SUBCOMMISSION FOR THE MIDDLE EAST

31. **appreciates** the efforts of the Subcommission specially as concerns the preparation and the presentation of the digital draft of the second edition of the *International Geological Map of the Middle East (IGMME) at 1:5 M scale* with the support of the Geological Survey of Iran, and
32. **urges** the completion as soon as possible of the compilation of the IGMME in order to be presented in final format as soon as possible to be submitted to a review committee prior to its publication, and
33. **thanks** the Geological Survey of Iran (GSI) for its effective and continuous support in the realization of CGMW maps (International Geological and Metallogenic Maps of the Middle East), and

SUBCOMMISSION FOR NORTHERN EURASIA

34. **Supports** the initiative of the national geological surveys of Russia, Sweden, Finland, Iceland, Denmark, the USA, Canada and Norway to collaborate with the Subcommissions for Northern Eurasia and Tectonic Maps for the compilation and publication of the *Tectonic Map of Circumpolar Arctic at 1:5 M scale* as part of the *Atlas of geological maps of Circumpolar Arctic at 1:5 M* under the aegis of CGMW and UNESCO, and

SUBCOMMISSION FOR AUSTRALIA-OCEANIA

35. **thanks** to Geoscience Australia for its offer to give access to the relevant digital data for the compilation of the

24. **apprécie** les progrès réalisées dans la préparation, pour 2009, par les Services géologiques d'Argentine (SEGEMAR) et du Chili (SERNAGEOMIN) de la *Carte géologique de la Patagonie au 1 :1 M*, et

SOUS-COMMISSION POUR L'ASIE MÉRIDIONALE ET ORIENTALE

25. **exprime** sa profonde satisfaction pour la préparation de la maquette presque complète de la *Carte géologique internationale de l'Asie au 1/5 M (IGMA)* exposée au stand de la Chine à Geoexpo 2008, et
26. **remercie** le Service géologique de Chine (CGS) pour sa prise en charge de la réalisation du projet IGMA ainsi que des réunions internationales et des ateliers de travail menés dans ce cadre, et
27. **souhaite** que la sous-commission pour Moyen-Orient puisse fournir, aussi vite que possible, une maquette de la deuxième édition de la *Carte géologique du Moyen-Orient à l'échelle du 1/5 M*, sous forme numérique, afin de compléter la partie du sud-ouest de la carte IGMA, et
28. **demande** aux Sous-commissions responsables de la cartographie des régions environnantes de fournir les informations numériques nécessaires pour compléter les secteurs appropriés de la carte, et
29. **remercie** le groupe de travail international d'IGMA 5000 de sa proposition de compiler, sur la base d'IGMA 5000, les cartes thématiques suivantes: la carte de ressources de l'Asie (hydrocarbures, ressources métalliques et non métalliques etc.), la carte géologique des risques, des cartes paléo-tectoniques et paléogéographiques de l'Asie, du Phanérozoïque des étapes tectoniques principales de l'Asie, la carte métamorphique de l'Asie, et la carte magmatique de l'Asie,
30. **exprime** à l'Acad. Ren Jishun, Coordonnateur de la carte IGMA, ses souhaits sincères pour un prompt rétablissement et une bonne santé, et de

SOUS-COMMISSION POUR LE MOYEN-ORIENT

31. **apprécie** les efforts de la Sous-commission en ce qui concerne particulièrement la préparation et la présentation de la maquette numérique de la deuxième édition de la *Carte géologique internationale de le Moyen-Orient à l'échelle du 1/5 M (IGMME)* réalisée avec l'appui du Service géologique d l'Iran, et
32. **recommande** l'achèvement dans les meilleurs délais de la compilation de l'IGMME afin qu'elle puisse aussitôt que possible être, dans sa forme complète, présentée pour soumission à un comité de lecture avant toute publication, et
33. **remercie** le Service géologique d'Iran (GSI) de son appui efficace et continu dans la réalisation des cartes de la CCGM (cartes géologiques et métallogéniques internationales du Moyen-Orient), et

SOUS-COMMISSION POUR L'EURASIE DU NORD

34. **soutient** l'initiative des Services géologiques nationaux de Russie, de Suède, de Finlande, d'Islande, du Danemark, des Etats-Unis, du Canada et de la Norvège pour qu'ils collaborent avec la S/C pour l'Eurasie du Nord et la S/C pour les Cartes tectoniques afin d'assurer la compilation et la publication de la *Carte tectonique circumpolaire de l'Arctique à l'échelle de 1/5 M* en tant qu'un élément de *l'Atlas des cartes géologiques circumpolaires de l'Arctique à 1/5 M* sous l'égide de la CCGM et de l'UNESCO, et

SOUS-COMMISSION POUR L'AUSTRALIE-OCEANIE

35. **remercie** Geoscience Australie de son offre de fournir les

Structural Map of the Southern Pacific Ocean for the 34th International Geological Congress (IGC) in Brisbane (Australia), and

36. **acknowledges** the completion of the first edition of the *1:1 M Digital Geological Map of Australia*, and

SUBCOMMISSION FOR ANTARCTICA

37. **thanks** Dr. G.E. Grikurov for his 17 years of efficient contribution to CGMW effort during his Vice-Presidency for Antarctica, and **welcomes** Dr. G. Leitchenkov as new CGMW Vice-President for Antarctica, and

38. **acknowledges** Dr. G. Leitchenkov's comprehensive update on the present status of the TEMPORE project, and

39. **notes with regret** that other priorities made it impossible to finalize the drafts of the Arctic and Antarctic maps before the 33rd IGC and the current CGMW General Assembly, as was originally planned, and

40. **appreciates** the progress achieved so far with preparation of the *Antarctic Structural Map* based on new legend, and looks forward to the soonest possible completion of the final draft and its approval by an Antarctica expert group, and **expects** its publication for the next CGMW General Assembly, and

THEMATIC SUBCOMMISSIONS

SUBCOMMISSION FOR TECTONIC MAPS

41. **appreciates** the cooperation between the Subcommissions for Northern Eurasia and Tectonic Maps in the realization of tectonic cartographic projects for the territory of Asia, and

42. **notes with satisfaction,** the achieved compilation of the *Tectonic Map of the Central Asia and adjacent areas at the scale 1:2.5 M* by the above-mentioned Subcommissions, and

43. **recognizes** the *Tectonic map of the Central Asia and adjacent areas*, besides its regional relevance, as a completed stage of the partial compilation of *the International Tectonic Map of Asia - ITMA-5000*, and

44. **acknowledges** the participation of the Subcommissions for the Northern Eurasia and Tectonic Maps in the compilation of the *Tectonic map of Central, Northern and Eastern Asia,*, as an extended version of the *Tectonic map of the Central Asia and adjacent areas*, considering it not only an important international solo project, but a first step of the compilation of *the International Tectonic map of Asia - ITMA-5000* as well, and **recommends** the use of this map in the compilation of national and regional drafts prepared for *ITMA-5000*, and

SUBCOMMISSION FOR METALLOGENIC MAPS

45. **acknowledges** the release of the *Digital Metallogenic Map of South America* and related databases by SEGEMAR and ASGMI, and

46. **appreciates** the launching of the *GIS Largest mineral deposits of the World* compiled by Academician D. Rundqvist and his group, in cooperation with the Russian-French Metallogenic Laboratory, and

47. **appreciates** the draft completion of the *World Metallogenic Map of Large and Superlarge Mineral Deposits* at 1:25 M and **recommends** that the General Coordinator, Acad. Pei Rongfu (Chinese Academy of Geological Sciences), arranges its publication following the CGMW standards, and

données numériques appropriées afin de permettre la compilation de la *Carte structurale de l'océan Pacifique* pour le 34ème Congrès Géologique International (CGI) à Brisbane (Australie), et

36. **prend acte** de l'achèvement de la première édition de la *Carte* géologique *de 1/1 M numérique de l'Australie*, et

SOUS-COMMISSION POUR L'ANTARCTIQUE

37. **remercie** le Dr. G. E. Grikurov pour ses 17 années d'une contribution efficace à l'effort de la CCGM durant sa Vice-présidence à la S/C Antarctique, et **souhaite la bienvenue** au Dr. G. Leitchenkov en tant que nouveau Vice-président de la CCGM pour l'Antarctique, et

38. **prend acte** de la mise à jour complète du Dr. G.Leitchenkov sur le statut actuel du projet de TEMPORE, et

39. **note avec regret** que d'autres priorités ont rendu impossible la finalisation des maquettes des cartes arctiques et antarctiques avant le 33ème CGI et la présente Assemblée générale de la CCGM, comme cela était prévu à l'origine, et

40. **apprécie** le progrès réalisé jusqu'ici dans la préparation de la *Carte* structurale *de l'Antarctique* bâtie autour de la nouvelle légende, et attend le plus tôt possible l'achèvement définitif du projet puis son approbation par un groupe d'experts de l'Antarctique, et **souhaite** sa publication pour la prochaine Assemblée générale de la CCGM, et

SOUS-COMMISSIONS THÉMATIQUES

SOUS-COMMISSIONS POUR LES CARTES TECTONIQUES

41. **apprécie** la coopération entre la S/C pour l'Eurasie du Nord et la s/c pour les cartes tectoniques dans la réalisation de projets cartographiques tectoniques concernant le territoire de l'Asie, et

42. **note avec satisfaction** la réalisation de la compilation de la *Carte tectonique de l'Asie centrale et des secteurs adjacents à l'échelle de 1/2,5 M* par les Sous-commissions mentionnées ci-dessus, et

43. **reconnaît** la *Carte tectonique de l'Asie centrale et des secteurs* adjacents, en sus de sa pertinence régionale, comme une étape dans la compilation partielle de la *Carte tectonique internationale de l'Asie - ITMA-5000*, et

44. **prend acte** de la participation de la S/C pour l'Eurasie du Nord et de la S/C pour les Cartes tectoniques dans la compilation de la *Carte tectonique de l'Asie centrale, septentrionale et orientale* qui constitue une version étendue de la *Carte tectonique de l'Asie centrale et des secteurs adjacents*, considérant qu'elle constitue non seulement un projet international important, mais aussi une première étape dans la compilation de la *Carte tectonique internationale de l'Asie - ITMA-5000*, et recommande l'utilisation de cette carte dans la compilation des maquettes nationales et régionales préparées pour ITMA-5000, et

SOUS-COMMISSION POUR LES CARTES MÉTALLOGÉNIQUES

45. **prend acte** de l'achèvement de la *Carte métallogénique numérique de* l'Amérique *du Sud* et des bases de données relatives par SEGEMAR et ASGMI, et

46. **apprécie** la publication du *SIG des gîtes minéraux géants du Monde*, compilé par l'Académicien D. Rundqvist et ses collaborateurs, en coopération avec le Laboratoire franco-russe de métallogénie, et

47. **apprécie** l'achèvement de la *Carte des gites minéraux géants du monde à 1/25 M* et recommande que le Coordinateur général, l'Académicien Pei Rongfu (Académie chinoise des sciences géologiques), se charge de sa publication selon les normes de la CCGM, et

48. **welcomes** the progress in the preparation of the *World Map of the Mineral Resources of the Oceans* at 1:25 M and **encourages** Acad. Pei Rongfu to present a draft for the next General Assembly in Paris 2010, and

49. **thanks** Acad. Pei Rongfu for the proposal of compiling a *Metallogenic Map of Asia* at 1:5 M and **recommends** the preparation of a feasibility study and to liaise with the Subcommission for East and South Asia and the IGMA coordination team before undertaking this project, and

50. **expresses** its satisfaction for the finalization of the digital draft of the *Metallogenic Map of Middle East* at 1:5 M by Dr. Aghanabati and **recommends** its publication by the Geological Survey of Iran (GSI), following the CGMW standards, for its presentation during the next General Assembly in Paris 2010, and

SUBCOMMISSION FOR HYDROGEOLOGICAL MAPS

51. **congratulates** Dr. W. Struckmeier for the preparation and publication of the 2008 edition of the *Groundwater Resources Map of the World* at the scales of 1:40 M and 1: 25 M and of the *International Hydrogeological Map of Europe (IHME) at 1:5 M scale*, and

52. **commends** the special efforts of the Subcommission for Hydrogeological Maps to finalize the *Groundwater Resources Map of the World at the 1:25 M scale* and **congratulates** the WHYMAP group for the printing of this important new global map, and

53. **thanks** the BGR for providing the coordination for the WHYMAP programme and in particular the GIS part and technical preparation for the publication of maps, and

54. **thanks** UNESCO for the continuous support of the WHYMAP activities and **welcomes** its extension to the 7th phase of the International Hydrological Programme (IHP) and **acknowledges** the excellent cooperation of geological experts and the water community to compile this map, partly fostered by the International Geoscience Programme (IGCP) and the International Hydrological Programme (IHP) steered by UNESCO, and

55. **asks** the Subcommission to continue its support in favour of the WHYMAP programme and **suggests** to improve the draft of the lithological map and integrate it into the WHYMAP GIS, and **offers** its support for the compilation of additional thematic layers that should be included in the WHYMAP GIS, and

56. **suggests** the inclusion of WHYMAP data into the OneGeology framework, and

57. **thanks** BGR and the Association of European Geological Surveys (EGS) for the publication, both on paper and digitally, of a mosaic at the scale of 1:5 M, of the 25 maps sheets of the long standing map series of the International Hydrogeological Map of Europe at the scale of 1:1.500 000 (IHME 1500), as a special contribution to the International Year of Planet Earth, and

58. **calls** upon the Geological Surveys in southeastern Europe to make a special effort, together with BGR being the editorial body of the IHME 1500 map series, to publish the draft map sheets of Budapest, Bucharest and Athens as soon as possible, and

59. **recommends** the digital hydrogeological map mosaic of Europe to be efficiently used for European processes such as the Water Framework Directive and the associated Groundwater Directive, to take due note of the existing hydrogeological knowledge, and

48. **apprécie** le progrès réalisé dans la préparation de la *Carte du Monde des ressources minérales des océans à 1/25 M* et encourage l'Académicien Pei Rongfu à en présenter une maquette pour la prochaine Assemblée générale à Paris 2010, et

49. **remercie** l'Académicien Pei Rongfu de sa proposition de compiler une Carte métallogénique de l'Asie à 1/5 M et **recommande** de préparer une étude de faisabilité et de se mettre en relation avec la S/C pour l'Asie du sud-est et l'équipe de coordination d'IGMA avant d'entreprendre ce projet, et

50. **exprime** sa satisfaction pour l'achèvement de la maquette numérique de la *Carte métallogénique de Moyen-Orient à 1/5 M* par le Dr. Aghanabati et **recommande** sa publication par le Service géologique d'Iran (GSI), selon les normes de la CCGM, pour sa présentation à la prochaine Assemblée générale à Paris 2010**,** et

SOUS-COMMISSION POUR LES CARTES HYDROGÉOLOGIQUES

51. **félicite** le Dr. W. Struckmeier pour la préparation et la publication de l'édition 2008 de la *Carte des ressources en eaux souterraines du* Monde aux échelles de 1/40 M et 1/25 M et de la *Carte hydrogéologique internationale de l'Europe (IHME) à 1/5 M* et,

52. **prend acte** des efforts particuliers de la S/C pour les Cartes hydrogéologiques pour achever la *Carte des ressources en eaux souterraines du monde à l'échelle du 1/25 M* et **félicite** le groupe WHYMAP pour l'impression de cette nouvelle et importante carte globale, et

53. **remercie** le BGR d'avoir assuré la coordination du programme de WHYMAP et en particulier de la partie SIG ainsi que de la préparation technique pour la publication des cartes, et

54. **remercie** l'UNESCO pour son support continu des activités de WHYMAP et **se réjouit** de leur prorogation dans la 7ème phase du Programme Hydrologique International (IHP) et **reconnaît** l'excellente coopération entre les experts géologiques et la communauté des hydrogéologues lors de la compilation de cette carte, en partie soutenue par le Programme International de Geoscience (IGCP) et le Programme Hydrologique International (IHP) animé par l'UNESCO, et

55. **demande** à la Sous-commission de continuer son soutien au programme WHYMAP, et **suggère** d'améliorer l'ébauche de la carte lithologique en vue de son intégration dans le SIG WHYMAP, et **offre** son support à la compilation de couches thématiques supplémentaires qui devraient être inclues dans le SIG de WHYMAP, et

56. **suggère** l'intégration de données WHYMAP dans le cadre de OneGeology, et

57. **remercie** le BGR et l'Association des Services géologiques Européens (EGS) pour la publication, tant sur papier que numériquement, d'une mosaïque à l'échelle de 1/5 M, des 25 feuilles de la *Carte Hydrogéologique Internationale de l'Europe à l'échelle de 1/1,5 M (IHME 1500)*, comme contribution spéciale à l'Année Internationale de la Planète Terre, et

58. **demande** aux Services géologiques d'Europe du sud-est de faire un effort spécial, en association avec le BGR en tant qu'éditeur de la série de cartes IHME 1500, pour publier les cartes préliminaires de Budapest, Bucarest et Athènes aussitôt que possible, et

59. **recommande** que la mosaïque de cartes hydrogéologiques numériques de l'Europe soit efficacement utilisée pour des directives européennes comme la Directive cadre sur l'eau et la Directive sur les Nappes phréatiques associée, et prenne en compte les connaissances hydrogéologiques existantes, et

SUBCOMMISSION FOR NATURAL HAZARDS MAPS

60. **expresses** its satisfaction for the new progresses made by the Geological Survey of Japan on the web based geohazard Map of East Asia which was open to the public in 2007, and
61. **expresses** its satisfaction for the release of the *Geological Hazards Map of the Andes* by the Geological Surveys of the Andean countries through the Multinational Andean Project, Geoscience for the Andean Communities (MAP:GAC), and
62. **takes note** of new proposals of geohazards maps in Asia and Southwest Pacific areas from the Geological Survey of India and Geoscience Australia respectively, and will continue discussions, and

SUBCOMMISSION FOR SEAFLOOR MAPS

63. **thanks** Dr. M. Munschy for his contribution to the activities of the Subcommission for Seafloor Maps, and
64. **congratulates** Dr. P. Miles, National Oceanography Center, Southampton (NOCS) for the finalization and publication of the *Structural Map of the North Atlantic Ocean at 1:20 M* on time for the 33rd IGC, and
65. **expresses** its thanks to NOCS and the Geological Survey of Norway (NGU) for their financial and scientific support for the realization and publication of the *Structural Map of the North Atlantic Ocean at 1:20 M*, and
66. **acknowledges** the endeavour of the President of the Subcommission for Seafloor Maps to assign an appropriate scientist to oversee the compilation of a *Structural Map of the South Atlantic Ocean at 1:20 M scale* in concert with the new North Atlantic map. This map is to be published by IGC34, and
67. **notes** that the officers of the Subcommission will also liaise closely with the hosts of the IGC in Brisbane in the preparation of the structural map of the South Pacific Ocean, and
68. **encourages** the preparation of a new *Structural Map of the Mediterranean domain* at the scale of 1:2 M under the coordination of Dr. Jean Mascle, Geosciences Azur (France), and
69. **supports** the compilation of the *Structural Map of the Caribbean domain at the 1:10 M scale* and **recommends** the realization of the workshop gathering the main compilers to be held in early 2009, and

SUBCOMMISSION FOR METAMORPHIC MAPS

70. **acknowledges** the work on a new map on the metamorphic evolution of the Eastern Mediterranean realm is in progress, and
71. **encourages** the seeking of funding for the final compilation and its publication for the 34 IGC in Brisbane, and

OTHERS MAPPING PROJECTS

GEOLOGICAL MAP OF THE WORLD AT 1:25 M SCALE

72. **congratulates** Dr. Philippe Bouysse for having compiled a fully upgraded onshore and offshore areas of the 3rd edition of the *Geological Map the World at 1:25 M* scale, and
73. **congratulates** Drs. Manuel Pubellier and Alain Rabaute, Ecole Normale Supérieure de Paris, for the realization of the *Structural Map of Eastern Eurasia* at 1:12.5 M, and **recommends** the publication of a volume of the "Faces" collection devoted to the explanation of this map, and

SOUS-COMMISSION POUR LES CARTES DE RISQUES NATUREL

60. **exprime** sa satisfaction pour les progrès faits par le Service Géologique du Japon sur la Carte de risques géologiques, accessible sur le web, de l'Asie de l'Est, et accessible au public en 2007, et
61. **exprime** sa satisfaction pour l'édition de la *Carte de risques géologiques des Andes* par les Services géologiques des pays Andins au travers du Projet Multinational Andin de Géosciences pour les communautés andines (MAP:GAC), et
62. **prend note** des nouvelles propositions de carte des géorisques asiatiques pour les régions Pacifique et du Sud-ouest émanant des Services géologiques de l'Inde et de l'Australie respectivement, et poursuivra les discussions à ce sujet et

SOUS-COMMISSION POUR LES CARTES DES FONDS SOUS-MARINS

63. **remercie** M. Munschy pour sa contribution aux activités de la Sous-commission pour les Cartes des Fonds Sous-marins et
64. **félicite** le Dr P. Miles du Centre National d'Océanographie de Southampton (NOCS) pour la finalisation et la publication de la *Carte Structurale de l'Océan Atlantique Nord à l'échelle 1/20 M*, à temps pour 33e CGI, et
65. **exprime** ses remerciements au NOCS et au Service Géologique de la Norvège (NGU) pour leur soutien financier et scientifique dans la réalisation et la publication de la *Carte Structurale de l'Océan Atlantique Nord à /20 M* et
66. **prend acte** de l'initiative du Président de la Sous-commission pour les Cartes des fonds marins de désigner un scientifique apte à superviser la compilation d'une *Carte Structurale de l'Océan Atlantique Sud à l'échelle 1/20 M* de concert avec la nouvelle carte Nord Atlantique. Cette carte doit être publiée pour l'IGC34, et
67. **prend note** que les membres de la Sous-commission travailleront aussi en liaison étroite avec les organisateurs de l'CGI de Brisbane pour la préparation de la carte structurale de l'Océan Pacifique Sud, et
68. **encourage** la préparation d'une nouvelle *Carte structurale du domaine Méditerranéen à l'échelle 1/20 M*, coordonnée par le Dr Jean Mascle, Geosciences Azur (France), et
69. **soutient** la compilation de la Carte Structurale du domaine Caraïbe à l'échelle 1:10 000 000 et recommande la **réalisation** d'un workshop au début de l'année 2009, réunissant les principaux compilateurs et

SOUS-COMMISSION POUR LES CARTES METAMORPHIQUES

70. **reconnaît** que la compilation d'une nouvelle carte de l'évolution métamorphique du domaine méditerranéen oriental progresse et
71. **encourage** la recherche de financement pour sa compilation finale et sa publication au congrès 34 CGI de Brisbane et

AUTRES PROJETS CARTOGRAPHIQUES

CARTE GÉOLOGIQUE DU MONDE à l'ÉCHELLE 1/25 M

72. **félicite** le Dr Philippe Bouysse pour avoir compilé une version actualisée pour les domaines continentaux et marins de la 3e édition de la *Carte géologique du Monde à l'échelle 1/25 M*, et
73. **félicite** les Drs. Manuel Pubellier et Alain Rabaute (Ecole Normale Supérieure de Paris), pour la réalisation de la *Carte Structurale de l'Eurasie Orientale à l'échelle de* 1/12,5 M et recommande la publication d'un volume de la collection "Visages" consacrée à l'explication de cette carte, et

GEOPHYSICAL MAPS AND BOOKLET

74. **expresses** its satisfaction for the realization and publication, since the last General Assembly, of two new geophysical maps: the *World Stress Map (WSM) at the scale of 1:46 M* and the accompanying digital database compiled under the general coordination of Dr. Oliver Heidbach from the Geophysical Institute of the University of Karlsruhe with the support of the Heidelberg Academy of Sciences and Humanities and published in July 2007, and the *Magnetic Anomaly Map of the World at 1:50 M* (WDMAM), an international cooperative project led by Dr. Juha V. Korhonen, prepared and printed with full support of the Geological Survey of Finland in 2007, and
75. **thanks** Prof. Mioara Mandea and Dr. Erwan Thébault, authors of the newest volume of the "Faces" series entitled *The Changing faces of the Earth's Magnetic Field* published in 2007 thanks to the cooperation of the GeoForschungsZentrum, the Institut de Physique du Globe de Paris and the CNRS, and
76. **approves** the realization of the project for the compilation of the *World Gravity Map (WGM) at the 1:50 M scale* by Drs. Sylvain Bonvalot and Anne Briais of the Bureau Gravimétrique International (BGI) which was previously approved by the IUGG General Assembly, 2007 Perugia, together with and accompanying explanatory booklet, and
77. **encourages** the realization of an updated digital version of the *Magnetic Anomaly Map of the World at 1:25 M scale*, and
78. **approves** the realization of a mapping of the *Observed Magnetic Anomaly Lineations and Tectonic Elements of the World's Oceans (MATEO)* under the general coordination of Dr. Jérôme Dymant, Institut de Physique du Globe de Paris, consisting in a global compilation of marine magnetic anomaly lineations and plate tectonic elements taken from a selected set of recent papers, and

STANDARDS AND MISCELANEOUS

79. **thanks** the International Commission on Stratigraphy (ICS) for the fruitful cooperation resulting in the publication of the *Geologic Time Scale 2008* on the occasion of the 33 IGC, this latest version including for the first time the CGMW color codes chart (CMYK and RGB) and **expresses** its wish for the continuation of this joint venture, and
80. **encourages** the extension of the Commission's activities to the domains of soil sciences and **recommends** to examine the feasibility of a Global Soil and Terrain Map in conjunction with the related organisations and UNESCO, and

OneGeology

81. **approves** the flow chart that defines the constructive relationships between CGMW and OneGeology and,
82. **agrees** the contribution of CGMW to OneGeology consisting in providing updated digital data at global scale (1:25 M – 1:5 M) of synthetic and coordinated geological, hydrogeological, tectonic, metallogenic, metamorphic and geophysical maps of continents and oceans, and
83. **acknowledges** the role of OneGeology in the worldwide diffusion of geological knowledge, and
84. **congratulates** the OneGeology team coordinated by Ian Jackson, initiator of OneGeology (a concept launched at the CGMW General Assembly in 2006) on their achievements in such a short space of time, and
85. **encourages** and **supports** the cooperation and linkage between OneGeology and CGMW through K. Asch,

CARTES GÉOPHYSIQUES ET LIVRET

74. **exprime** sa satisfaction pour la réalisation et la publication, depuis la dernière Assemblée générale, de deux nouvelles cartes géophysiques : la *Carte du Monde des contraintes tectoniques à l'échelle de 1/46 M (WSM)* avec sa base de données numérique, compilée sous la coordination générale du Dr Oliver Heidbach (Institut Géophysique de l'Université de Karlsruhe), avec le soutien de l'Academy of Sciences & Humanities de Heidelberg et publiée en juillet de 2007, et la *Carte des anomalies magnétiques du Monde à 1/50 M (WDMAM)* au travers d'un projet de coopération internationale mené par Dr J. V. Korhonen, et préparée et imprimée entièrement grâce au Service géologique de Finlande en 2007, et
75. **remercie** le Prof. Mioara Mandea et le Dr Erwan Thébault, auteurs du tout nouveau volume, en anglais, de la série "Visages" intitulé *The Changing faces of the Earth's Magnetic Field* et publié en 2007, grâce à la coopération du GFZ (GeoForschungsZentrum), de l'Institut de Physique du Globe de Paris et du CNRS et
76. **approuve** la réalisation du projet de compilation de la *Carte gravimétrique du Monde (WGM) à l'échelle 1/50 M* avec une notice d'accompagnement, par les Drs. Sylvain Bonvalot et Anne Briais du Bureau Gravimétrique International (BGI), projet ayant été auparavant approuvé par l'Assemblée générale IUGG 2007 à Perugia, et
77. **encourage** la réalisation d'une version numérique actualisée de la *Carte des anomalies magnétiques du Monde à l'échelle 1/25 M,* et
78. **approuve** la réalisation d'une cartographie des *Anomalies magnétiques observées et des éléments tectoniques des océans du Monde (MATEO)* sous la coordination générale de Dr Jérôme Dyment, Institut du Physique du Globe de Paris, consistant en une compilation globale des anomalies magnétiques marines et des éléments de tectonique des plaques à partir d'une sélection d'articles récents, et

STANDARDS ET DIVERS

79. **remercie** la Commission Internationale de Stratigraphie (ICS) pour la coopération féconde aboutissant à la publication de *l'Echelle des Temps Géologiques 2008* à l'occasion du 33^{e} CGI, cette dernière version incluant pour la première fois les codes chromatiques CGMW (CMYK et RGB), et **exprime** son souhait de poursuivre cette coopération, et
80. **encourage** l'extension des activités de la Commission au domaine des sciences du sol et **recommande** la réalisation d'une étude de faisabilité d'une Carte mondiale des sols et des terrains, conjointement avec les organisations concernées et l'UNESCO, et

OneGeology

81. **approuve** l'organigramme qui définit les rapports constructifs entre CGMW et OneGeology et,
82. **accepte** la contribution de la CCGM à OneGeology pour la mise à disposition des données numériques actualisées à l'échelle globale (1/25 M–1/5 M) de cartes synthétiques et coordonnées de type géologique, hydrogéologique, tectonique, métallogénique, métamorphique et géophysique, des continents et des océans, et
83. **prend acte** du rôle de OneGeology dans la diffusion mondiale des connaissances géologiques, et
84. **félicite** l'équipe de OneGeology coordonnée par Ian Jackson, initiateur du projet OneGeology (un concept né à l'Assemblée générale de la CCGM en 2006) pour son travail accompli dans ce court espace de temps, et
85. **encourage** et **soutient** la coopération et le lien entre

CGMW Vice-President for Europe, as member of the OneGeology core management team, and

86. **appreciates** the BGR lead and CGMW involvement in the scientific Work package "Data specification and harmonisation" in the new EU eContentplus project OneGeology-Europe starting in September 2008.

CGMW

The Bureau presented the conclusions of the Financial Committee concerning CGMW membership fees, unchanged since 2002.

The creation of new categories (6 instead of 4) is proposed as follows:

- 300 € for countries having tight budget restrictions
- 600 €
- 1 200 €
- 2 000 €
- 3 000 €
- More than 4 600 €

Category upgrading will be proposed on a voluntary basis.

THESE RESOLUTIONS WERE ADOPTED AT THE LAST PLENARY SESSION OF THE GENERAL ASSEMBLY ON SATURDAY AUGUST 9, 2008 AT THE 33RD IGC IN OSLO, NORWAY. THE CGMW EXECUTIVE BUREAU THANKS ALL PARTICIPANTS TO THE GENERAL ASSEMBLY FOR THEIR PARTICIPATION AND CONTRIBUTIONS TO THE DISCUSSIONS AND EDITION OF THE PRESENT RESOLUTIONS.

OneGeology et la CCGM par l'intermédiaire de K. Asch, Vice-président de CGMW pour l'Europe, et membre de l'équipe de direction de OneGeology, et

86. **apprécie** le rôle moteur du BGR et l'implication de la CCGM dans le travail d'élaboration de l'ensemble scientifique concernant la «Spécification et harmonisation des données" dans la nouvelle structure UE eContentplus OneGeology-Europe débutant en septembre 2008.

CGMW

Le Bureau a présenté les conclusions du Comité Financier concernant les cotisations des pays membres de la CCGM, sans changement depuis 2002.

Il est proposé la création de nouvelles catégories (6 au lieu de 4) comme suit :

- 300 € pour des pays subissant d'importantes restrictions budgétaires
- 600 €
- 1 200 €
- 2 000 €
- 3 000 €
- Plus de 4 600 €

Le choix de catégories est proposé sur une base facultative.

Ces résolutions ont été adoptées à la dernière Séance Plénière de l'Assemblée Générale le samedi 9 août 2008 à l'occasion de la 33e CGI à Oslo, Norvège. Le Bureau Exécutif CCGM remercie tous les participants à l'Assemblée Générale pour leur participation et leur contribution aux discussions et à l'édition des présentes résolutions.

CHANGES ON CGMW BUREAU MEMBERS

Submitted to the approval of CGMW Bureau Members and the ratification by the General Assembly to be held on August 9, 2008 Oslo – 33rd IGC

Resignations and nominations proposed

Subcommission	Outgoing	Nomination	
		Name	**Organisation/Country**
ANTARCTICA	Dr. G. Grikurov	Dr. German Leitchenkov, Vice-President	VNIIOkeangeologia (Russia)
MIDDLE EAST		Dr. Abdollah Saidi	National Geosciences Database of Iran
SEAFLOOR MAPS	Dr. M. Munschy	Dr. Y. Lagabrielle	Géosciences Montpellier, CNRS (France)
GEOPHYSICAL MAPS		Dr. M. Mandea	Deutsches GeoForschungsZentrum, Potsdam (Germany)

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CGMW Plenary Assembly / *Assemblée Plénière de la CCGM*
Oslo, 33rd IGC – August 9, 2008

List of maps displayed during sessions
(published or drafts)

Liste des cartes exposées pendant les séances
(publiées ou maquettes)

ASIA

CHINA
Institute of Geology, Chinese Academy of Geological Sciences

- *Geological Map of Asia*
  1:5 M, draft. Compiler: IGMA team

AUSTRALIA/OCEANIA

AUSTRALIA
Geoscience Australia

- *Surface Geology of Australia*
  1:5 M, draft. Paper based on 1:1 M scale digital data. Compiler: Ollie Raymond
  Conctact: oliver.raymond@ga.gov.au

EURASIA

RUSSIA

VSEGEI

- *Tectonic Mzp of Central Asia and Adjacent Areas*
  1:2 500 000, published. Compilers: O. Petrov, Yu. Leonov

VNIIOkeangeologia, St. Petersburg

- *Antarctic Tectonic Map* (part of the map from 0° to 90° W)
  1:10 000 000, draft. Dr. G. Leitchenkov

EUROPE

EUROPE

Federal Institute for Geosciences and Natural Resources (BGR)

- *International Geological Map of Europe and Adjacent Areas*
  1:10 000 000, reduced version, published in 2007. Compiler: Dr. K. Asch

Federal Institute for Geosciences and Natural Resources (BGR)

- *International Quaternary Map of Europe*
  1:2 500 000, published specially for the IYPE in 2008. Compiler: Dr. K. Asch & A. Müller

EuroGeoSurveys, BGR, UNESCO and CGMW

- *International Hydrogeological Map of Europe (map mosaic)*
  1:5 000 000, draft 2008. Compiler: Dr. W. Struckmeier

IRELAND
Geological Survey of Ireland

- *Bedrock Geological Map of Ireland*
  1:500 000, published in 2006. Contact: Dr. M. Carter

Geological Survey of Ireland

- *Landscape and Rocks of the Burren*
  1:50 000, published in 2008. Contact: Dr. M. Carter

Geological Survey of Ireland

- *Bathymetry Offshore of Ireland*
  1:500 000, draft Contact: Dr. M. Carter

CGMW maps

- *International Metallogenic Map of the Middle East*
  1:5 000 000, draft. Compiler: Dr. A. Aghanabati – CGMW S/C for Metallogenic Maps
- *International Geological Map of the Middle East*
  1:5 000 000, draft. Compiler: CGMW S/C for the Middle East
- *Tectonic Map of Africa*
  1:5.000.000, draft. Initiated by Prof. J. Souy
  CGMW S/C for Africa. Dr. F. Toteu & Dr. J. Milesi.
- *Groundwater Resources of the World*
  1:25 000 000 published in 2008, Compiler: Dr. W. Struckmeier, CGMW S/C for Hydrogeological Maps.
- *Geological Map of the World*
  1:25.000.000, draft 2008. Compiler: Dr. Ph. Bouysse
- *Structural Map of Eastern Eurasia*
  1:12 500 000 published in 2008, Compiler: Dr. M. Pubellier.
- *Structural Map of the North Atlantic*
  1:20 000 000 published in 2008, Compiler: Dr. P. Miles, CGMW S/C for Seafloor Maps
- *Geological Time Scale 2008*
  Published in 2008, International Commission on Stratigraphy

CONTINENTAL SUBCOMMISSIONS

SOUS-COMMISSIONS CONTINENTALES

Reports

SUBCOMMISSION FOR AFRICA

CGMW Vice-President for Africa, Prof. Sospeter Muhongo.
Secretary General, Prof. Félix Toteu.
Deputy Secretary General, Dr. Jean-Pierre Milesi

THE INTERNATIONAL TECTONIC MAP OF AFRICA

J. P. Milesi, D. Frizon de Lamotte, G. de Kock, F. Toteu

The first edition of the Tectonic Map of Africa at 1:5 M was co-published in 1968 by CGMW and UNESCO under the coordination of Anne Faure-Muret and Georges Choubert. This map was published before the development of the plate tectonics concept and the systematic use of geochronology.

The launching of this second edition of the International Tectonic Map of Africa was decided in Gaborone, Botswana, during a workshop of the CGMW Sub-commission for Africa, in November 1987 by R. M. Schackleton (Imperial College, U.K.), J. Sougy (University of Marseille, Fr), F. J. Coertze (Council for Geosciences, CGS, Z.A), F. W. Dunning (British Geological Survey, U. K.), J. Marques (Inst. Nac. Geologia, Moçambique), M. A. O. Rahaman (University of Ife, Nigeria), B. T. Rumvegeri (University of Lubumbashi, Zaire), the map was placed under the responsibility of J. Sougy and R. Schackleton. Since then, the map is under preparation.

The course of action consisted basically in the analysis of extensive data collected in different African countries, which was subsequently updated and adjusted, in particular as concerns the structural and geochronological data. All along the two decades of this process, a number of meetings and workshop, mainly sponsored by UNESCO, were held in: Pretoria, Z. A., 28-29 June 1990; Harare, Zimbabwe, 24-26 September 1991; Franceville, Gabon, 29 April-2 May 1992; Dodoma, Tanzania, 26-29 May 1992; Dakar, Senegal, 25 January-2 February 1993; Cairo, Egypt, 5-8 April 1993; Mbabane, Swaziland, 14-16 September 1993; Tripoli, Libya, 10-16 October 1993; Damas, Syria, 11-19 December 1993; Abidjan, Ivory Coast, 2-10 May 1994; Windhoeke, Namibia, 29 August-1 September 1994; Johannesburg, Z. A., 3-7 April 1995; Pretoria, Z. A., 2-17 April 1995; Jerusalem, 23 August-2 September 1995; Nairobi, Kenya, 9-13 October 1995; Cairo, Egypt, 17-25 November 1996; Douala, Cameroon, 4-20 March 1997; Antananarivo, Madagascar, 17-30 August 1997; Capetown, Z. A., 27 June-2 July 1999; and International Geological Congress (IGC) in Beijing 1996, Rio de Janeiro 2000, Florence 2004, Oslo 2008. This allowed the legend to be in continuous evolution -up to now- in order to adapt to new findings and concepts, keeping in mind the aim to provide a legible map.

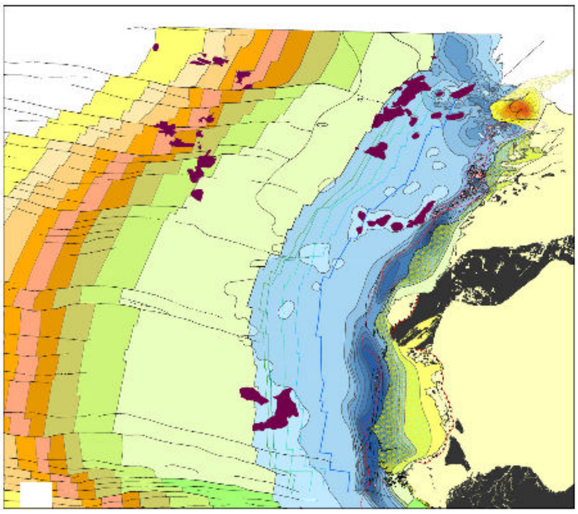
As from 1984, the participation of R. Shackleton was gradually relayed by J. Sougy alone. Some years later, C. Van Vuuren and G. De Kock (CGS, Z.A.) joined him and undertook the graphic synthesis and GIS work of the southern part. This map and database were completed in 2003 and presented in 2004 at the 32th IGC in Florence accompanied by a draft of the northern part consisting in the assembling of the digitalized drafts of J. Sougy and those of J.P. Milesi who compiled an area located between the Equator and parallel 16° N.

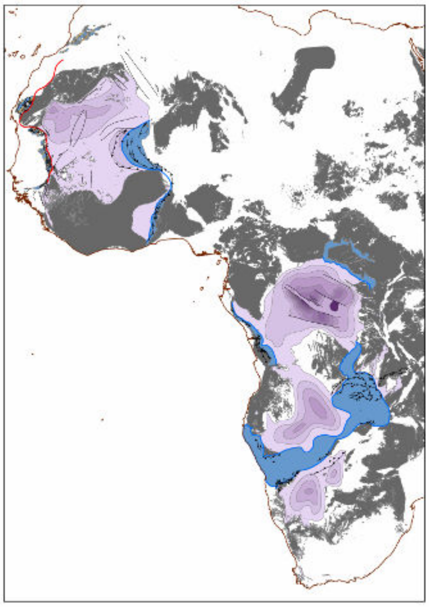
The basement of the northern part of the African continent was afterwards redesigned by J. P. Milesi at BRGM (2005-2006), with the assistance of F. Ralay and J.M. Leistel, and then displayed and discussed during a workshop at the 21st Colloquium on African Geology (CAG 2006) in

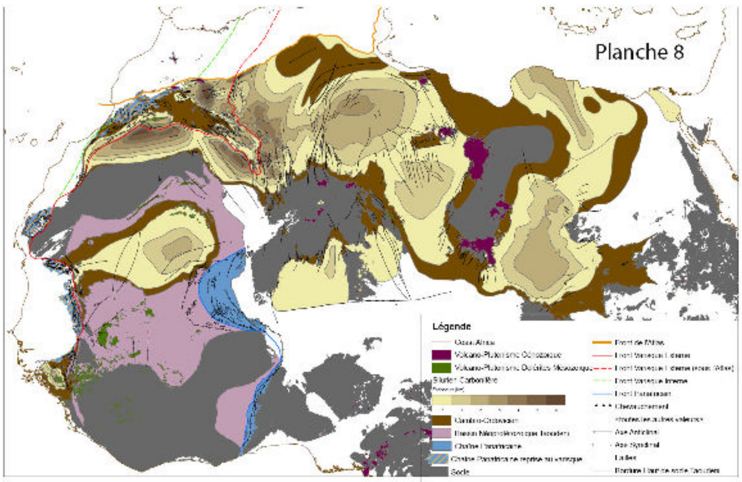
Maputo (G. de Kock, D. Delvaux, H. Fritz). J. P. Milesi, with contributions from AREVA (2007-2010), completed and harmonized the northern and southern maps using the most recent available data, while F. Toteu reviewed the characteristics of the magmatism. Thanks to a grant and to the unpublished data provided by the TOTAL oil company to CGMW (2008-2009), the map of onshore and offshore basins was entirely compiled and drawn by D. Frizon Delamotte and C. Raulin (University of Cergy-Pontoise), and displayed and discussed at the 22nd CAG in Tunis (2008).

The map and the GIS designs are the result of a long, continuous, and cooperative effort to upgrade each step of the building stage of the project. As from 2003, the GIS of the Austral part was provided by C. Van Vuuren (CGS). After the N-S geologic harmonization was performed (J. P. Milesi, D. Frizon de Lamotte), F. Chêne ensured the digital homogenization of the northern and southern parts of the GIS.

A pre-press draft of the map will be displayed at the CGMW General Assembly to be held on 14th - 15th February 2010, UNESCO, Paris.







SUBCOMMISSION FOR SOUTH AMERICA

By CGMW Vice-President for South America, Dr. Carlos Schobbenhaus and Secretary General, Dr. José Macharé Ordóñez

The activities of the Subcomission for South America in 2007 were related to the following projects:

- ***Tectonic Map of South America at 1:5 M (***new edition);
- ***Geological and Mineral Resources Map of South America at 1:1 M (GIS-South America 1:1 M) and related data basis***.

The last one represents an initiative of the Ibero-American Association of Geological and Mining Surveys (ASGMI) with endorsement of the CGMW.

The ***Tectonic Map of South America Project*** is under execution through the continental coordination of Prof. Dr. Umberto G. Cordani from the University of São Paulo and of Prof. Dr. Victor Ramos from the University of Buenos Aires. The first one is responsible for the South American Platform and the second one for the Andean Cordillera. In 2007 two vice-coordinators were invited by the South America S/C to join the project: Geol. Inácio de Medeiros Delgado of the Geological Survey of Brazil (CPRM), and Dr. Marcelo Cegarra of the Geological and Mining Survey of Argentina (SEGEMAR). Both geological surveys have an essential participation in the execution of the project. The activities during the period were pointed by an important meeting held in Montevideo, Uruguay, in June 2007, and by several smaller working meetings. The meeting of Montevideo aimed to assess the state of the art of the project and specially to discuss the content and format of the legend to be adopted and also the various layers to be inserted in the GIS underpinned project. The former 1:5M base of South America was ortho-rectified by the CPRM through Landsat GeoCover 2000 mosaics, according the WGS 84 reference frame. A draft of the Tectonic Map of South America will be presented in the next IGC in Oslo.

The ***GIS-South America 1:1 M Project*** is made up by 92 (whole and partial) map sheets. Each map sheet forms a rectangle of 6^o of longitude and 4^o of latitude. About 40% of the 1:1M map was performed by the Geological Survey of Brazil covering 46 (whole and partial) GIS underpinned map sheets of the whole territory of Brazil. Currently, map sheet SH.21 (Monte Caseros/Uruguaiana/Arapey) of the *GIS-South-America 1:1 M Project,* covering part of the territories of Argentina, Brazil and Uruguay is being executed by the geological surveys of these countries with support from the Southern Common Market (Mercosul or Mercosur). This is the first map sheet of the 1:1M project involving more than one country. It aims mainly the integration and revaluation of geological map data at 1:1M scale and the harmonisation of the geology along the borders, besides the construction of a only legend readable in English and the language of each country involved. In 2007 a technical meeting took place in the border area of the 3 involved countries (Monte Caseros, Argentina). Furthermore, the CPRM organized a workshop of ArcGis geoprocessing techniques and data organization in Brazil, aiming the on the job knowledge equalizing of the team, in which the representatives of five geological surveys participated. A draft of SH.21 map sheet has been completed. For 2008 the CPRM and the BRGM are scheduling the start of map sheet NA.22 (Macapá), in the area of border between Brazil and French Guyana.

SUBCOMMISSION FOR THE MIDDLE EAST

By CGMW Vice-President, Dr. A. Haghipour

The CGMW-Subcommission for the Middle East since its last report to the General Assembly has been following up actively the two mapping projects currently in preparation. In May 2009 a regional meeting on the International Geological Map of the Middle East (IGMME) was convened in Tehran. Representatives of the majority of the countries of this area attended this meeting.

International Metallogenic Map of the Middle East

Thanks to the support and data provided by the Geological and Mineral Survey of Iran, the digitized draft of the *International Metallogenic Map of the Middle East* at the scale of 1:5 M scale was completed and submitted by its main coordinator, Dr. A. Aghanabati, to critical perusal of the head of the CGMW Subcommission for Metallogenic Maps, Dr. E. Zappettini. The modifications suggested by Dr. Zappettini were implemented and a final draft should be presented at the 2010 General Assembly.

MINUTES OF THE INTERNATIONAL MEETING ON THE GEOLOGY OF MIDDLE EAST AND WORKSHOP ON THE 1:5 M INTERNATIONAL GEOLOGICAL MAP OF MIDDLE EAST (IGMME 5000)

Tehran, Iran, May 19-24, 2009

List of participants: Prof. Jean-Paul Cadet (CGMW President); Dr. Philippe Rossi (CGMW Secretary General); Dr. Manuel Pubellier (CGMW Secretary General elect); Prof. Roland Oberhänsli (President of the CGMW S/C for Metamorphic Maps, Germany); Dr. Abdolazim Haghipour (CGMW Vice-President for the Middle East, Iran); Dr. Abdollah Saidi (Secretary General of the CGMW S/C for the Middle East, Iran); Dr. Ghazar Galoyan (Armenia); Dr. Marif Zeynalov (Azerbaidjan); Prof. Jin Xiaochi (China); Prof. Niu Baogui (China); Dr. Wang Jun (China); Dr. Shoba Adamia (Georgia); Dr. Manuel Berberian (Iran); Dr. S.A. Aghanabati (Iran); Mr. Alireza Amrikazemi (Iran); Mr. Jalil Ghalamghash (Iran); Dr. Mansour Ghorbani (Iran); Ms. Tayebeh Kiani (Iran); Mrs. Razieh Lak (Iran); Dr. Hassan Mirnejad (Iran); Mr. Massoud Morsali (Iran); Mrs. Farah Rahman (Iran); Mr. Alireza Shahidi (Iran); Dr. Morteza Talebian (Iran); Mr. Pezhavak Didar (Iran); Dr. Azin Ostovar (Iran).Dr. Mazin Tamar-Agha (Iraq); Mr.Mohammad Talal Beirakdar (Syria); Mr. Zafer Al Jallad (Syria) and Dr. Mohamed Amin Moghallis (Yemen).

The International Meeting on the Geology of Middle East was held in Tehran, Iran, from19 to 24 May, 2009. About 20 scientists from 8 countries participated in the workshop.

The main aims of the workshop were:

- to examine the completion of the first completed digital draft of the second edition of the IGMME;
- to examine the finalization of the digital draft of the Metallogenic Map of the Middle East at1:5 M by Dr. Aghanabati;
- to examine new projects prior to their presentation to the next CGMW General Assembly (February 2010).

The discussion was very fruitful.

General considerations

The participants:

1. thank Eng. Mehrabian, Minister of Industries and Mines of Iran and Eng. Korehie, Deputy Minister of Industries and Mines and General Director of the Geological Survey of Iran to have supported this meeting and for their kind encouragements and;
2. express their sincere thanks to the Geological Survey of Iran (GSI) for its full support to the CGMW SUBCOMMISSION for the Middle East and for the organization of this meeting and for its warm welcome to Tehran and hospitality during the workshop and the associated field trip and;
3. underlined the high quality of the preparation of the Workshop and;

4. congratulate Dr. A. Haghipour and Dr. A. Saidi and their GIS team for the important work done to achieve the first complete digitized IGMME5000 version on time for this workshop;
5. acknowledge the GIS department for its presentation of the IGMME associated database and;
6. acknowledge that IGMME is carried out under the aegis of CGMW and with the support of the UNESCO and on line with the resolutions adopted during the CGMW General Assembly in August 2004 and,
7. were informed this map will help completing the Middle East part of the IGMA5000 project carried out by Prof. Acad. Ren Jishun, and that the ArcInfo file of the map presented at the workshop was transmitted to Dr. Wang Jun for this purpose and;
8. express their satisfaction for the finalization of the digital draft of the Metallogenic Map of Middle East at 1:5 M by Dr. Aghanabati under the auspices of the subcommission of the Middle East, and,
9. recommend to Dr. Aghanabati to send the map to Dr. E. Zappetini, president for the CGMW subcommission for metallogenic maps, prior to the printing of the map by the Geological Survey of Iran (GSI), following the CGMW standards, the map be presented during the next 2010 General Assembly in Paris, and;
10. appreciated lectures on the Geology of the Middle East countries (Armenia, Azerbaidjan, Georgia, Iran, Iraq, Syria and Yemen given on May 19 & 20 and;
11. appreciated the presentation of near completion of the IGMA project (map and database) by Prof. Jin Xiaochi and Dr. Wang Jun to be achieved for the next 4th workshop in Beijing during October 2009 and;
12. were informed by Dr. M. Pubellier (CGMW S/G elect) of the last achievements of the OneGeology project and the symbiotic relationships between the OneGeology and the CGMW and;
13. were informed that the GSI is willing to be, from now, an active participant of OneGeology, and were informed by other participants of their intention to join the project and;
14. were informed that the IGMME would be on line with the OneGeology when completed and;

Resolutions concerning the modifications, editing and the edition of the IGMME

15. express their congratulations and acknowledgments to the Geological Survey of Iran (GSI) for the complete digitization of the IGMME5000 and associated data base and;

Oceanic part

16. ask to use stratigraphic colours instead of different shades of blue colours without other modifications and;
17. suggest to take substantial Quaternary infills such as deltas (i.e Nile, Indus …) and;
18. propose to complete major submarine structures (faults) to be send by the CGMW S/G and;

Continental part

19. propose to proceed with homogenization of the faults in terms of density and hierarchy according to their major geodynamic significant feature (CGMW S/G can provide scientific support) and;
20. ask to ensure the fit of the structures on the lithologic boundaries (namely geometric relationships between faults and the Quaternary sediments) and;
21. suggest to test the fit of the map on the SRTM map prior to delivering the digital version of the map and;
22. asked that the geographic names on the topobase map relevant to each country will be adopted; pointed out that special attention has to be paid to cross boundary geographic names: only those names which have been acknowledged by all the countries concerned can be adopted; and asked to use English names for all geographical objects, such as lakes, mountains, peaks, seas etc." and ;
23. observe that relevant patterns have to be chosen to be legible as best as possible on the colour background and;

Reviewing and editing procedures

24. urge each participant country in the workshop to carefully review its relevant territory and to send the corrections to the GSI (cgmwmiddleeast@gsi.ir) with a copy (jpeg file or paper) to the CGMW S/G (ccgm@club-internet.fr), as soon as possible and in any case prior to the 1st of August 2009 and;
25. were informed that following the CGMW standard procedures to ensure the highest international scientific quality, the maps will be reviewed by independent reviewers on time to be taken into account and;

26. asked the IGMME be dated 2009 and printed and distributed at the next CGMW General Assembly to be held in 15-16 February 2010, Paris UNESCO and;
27. approve the following calendar prepared in order the maps be printed for the CGMW General Assembly in February 2010:

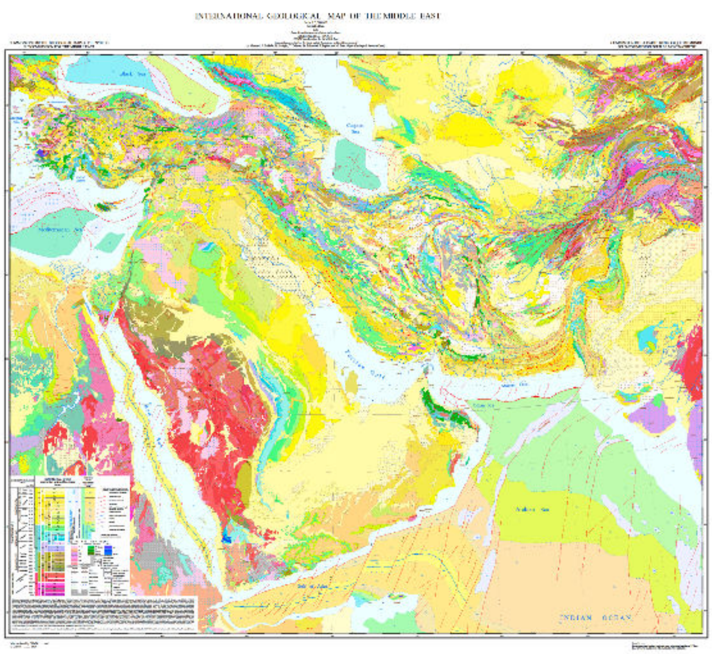
<table>
<tr><th>May 2009</th><th>June 2009</th><th>July 2009</th><th>August 2009</th><th>September 2009</th><th>October 2009</th><th>November 2009</th><th>December 2009</th><th>January 2010</th></tr>
<tr><td colspan="3">Review by relevant countries</td><td colspan="3">IGMME complements (GSI)</td><td rowspan="2">Proof</td><td rowspan="2">Pre press proof</td><td rowspan="2">Printing</td></tr>
<tr><td colspan="4">Review by CGMW reviewers</td><td colspan="2"></td></tr>
</table>

New projects to be presented to the CGMW Bureau and General Assembly

28. acknowledge the proposal on preparation of the Medical Geology Commission at the CGMW to prepare the Medical Geology Maps, presented by Mrs. Farah Rahmani and;
29. acknowledge the support of the ICMA for this initiative, a copy of a letter from its President Dr. O. Selenius was distributed, and;
30. ask that this proposition be favourably presented to the CGMW Bureau and the General Assembly, and ask to CGMW Executive committee to contact Dr. O. Selenius to discuss this aim and;
31. acknowledge the proposal on preparing a Medical Geology database of the Middle East at 1:5M scale, and think that a preliminary draft of a part of this map to be included, as an example of feasibly, to the proposal on creation of the Medical Geology Commission at the CGMW;
32. acknowledge the proposal on preparing the Atlas of the Middle East Marine Geology at 1:5M scale, presented by Dr. Razieh Lak;
33. recognize the scientific interest of the project, but underline the difficulties in collecting new data, recommend to document this database project and suggest to focus on the preparation of a structural map project of the Caspian Sea for the next 2010 CGMW Bureau and;
34. acknowledge the proposal on preparing the Geotectonic map of the Middle-East, presented by Dr. Hamid Nazari, and,
35. recognize the scientific community needs this information, support this initiative, and recommend to join international effort to this aim, ask to prepare a proposal for the next 2010 CGMW General Assembly and;
36. acknowledge the proposal for the preparation of the Middle-East Earthquake Hazard Map presented by Dr. Morteza Talebian and;
37. recognize the very scientific and vital interest of this map, complementary with other projects (namely the Geotectonic map), ask the coordinator to contact international groups working on this aim to prepare a proposal for the project to the next 2010 CGMW General Assembly;
38. acknowledge the proposal on preparing the Middle-East Magmatic Map, presented by Dr. Jalil Ghalamghash and,
39. recognize the scientific interest of this project, note the interest to collect the information dealing with magmatic rocks in a database, in order to save the detailed information, and question how to represent the data in a large scale map and propose to prepare a documented proposal of this database project to be proposed in the next 2010 CGMW General Assembly and;
40. acknowledge the proposal on preparing the Geotourism map presented by Dr. Alireza Amrikazemi;
41. propose that CGMW inform the relevant commissions of the IUGS and the UNESCO, in order to ensure the best coordination in preparing such maps and;
42. acknowledges the proposal on preparing the Middle-East Water Resources Map presented by Dr. Massoud Morsali;
43. recognize the vital interest of this project which have to be supported and shared with the CGMW subcommission on Hydrogeological maps, and international institutions dealing with hydrogeology (UNESCO, IAH …) to reinforce the proposal prior to its submission to the CGMW Bureau meeeting and General Assembly;
44. acknowledge the proposal on preparing the Middle East Atlas of Quaternary Maps at 1:5M scale, from the GSI Quaternary group, presented by Ms. Azin Ostovar and;

45. recognize the scientific and environmental interests of this Quaternary Map, underline the necessary international cooperation -as noted by the GSI Quaternary group-, recommend to get in touch with the INQUA (International Quaternary Association), and ask to prepare a proposal for the 2010 CGMW Bureau meeting and General Assembly and;
46. acknowledge the proposal on preparing the Middle East Magnetic Airborne Geophysics Map presented by Mr. Naser Abedian;
47. recognize the scientific and economic interests of this project but underline the difficulty to collect the 1km x 1km grid (bearing in mind the recent experience of the CGMW WDMAM (World Digital Magnetic Anomaly Map) map based on a 5km x 5km grid), support this project that has to be documented and presented to the next 2010 CGMW Bureau meeting and General Assembly and;
48. acknowledge the proposal on preparing the Middle East Map of the Precious and Semi-Precious stones presented by Mr. Ghorbani;
49. recognize the interest of this map, and propose to prepare a proposal of the necessary data bank to be submitted to the next 2010 CGMW Bureau meeting and General Assembly and;
50. acknowledge the proposal on preparing the Middle East Ontology for the components of the Geological Map presented by Ms. Tayabeh Kiani and;
51. recognize the interest of this proposal and recommend to ensure a connection between the CGMW DIMAS and the IUGS's commission for the Management and Application of Geoscience Information (CGI) that deals with the map standards, in relation with the Technical Working Group (TWG) of OneGeology prior to propose the project to the next 2010 CGMW Bureau meeting and General Assembly.
52. acknowledge the proposal on preparing the Middle-East Geochronological map by Dr. Hassan Mirnejad, and,
53. recognize the scientific interest of this project, note the interest to collect the information dealing with geochronology in a database in order to save the detailed information, and propose to prepare a documented submission of this database project for the next CGMW General Assembly.
54. recommend, in order to ensure the preparation of proper proposals for the CGMW Bureau meeting and General Assembly, that the names of the coordinator and the institutions for each project be identified, and ask that a proposition be sent to CGMW Secretariat General in Paris before December 15, 2009.

These resolutions were adopted at the International Meeting on the Geology of Middle East and the workshop on the 1:5 M International geological map of Middle East (IGMME 5000) held in Tehran, Iran, May 19-24, 2009. The CGMW Executive Bureau thanks all participants to for their participation and contributions to the discussions and edition of the present resolutions.



Draft of the IGMME map presented as at October 2009

Sub-commission for Northern Eurasia
Vice-President: O. V. Petrov,
Secretary General: S. P. Shokal'sky.

Sub-commission for South East Asia
Vice-President: Ren Jishun
Secretary General. H. K. Gupta
Deputy Secretary General: Peng Qiming.

Sub-commission for Middle East
Vice-President : A. Haghipour
Secretary General: A. Saidi.

THE INTERNATIONAL GEOLOGICAL MAP OF ASIA

Ren Jishun, main Coordinator

The fourth workshop on the 1:5M International Geological Map of Asia (IGMA5000) was held in Beijing, China, from October 24 to 27, 2009. About 80 scientists from 14 countries participated in the workshop.

MINUTES OF THE FOURTH WORKSHOP (IGMA5000)

The main aims of the 4th workshop were: 1) to display and review the draft of IGMA 5000; 2) to present the geological maps of related countries and areas, which have been published and will be published; 3) to discuss how to improve and perfectly complete the IGMA 5000 database; 4) to discuss the plan of writing the explanatory book of the IGMA 5000, and the schedule and the contents of the book "Geology of Asia"; 5) to have academic exchanges in the research of Asian geology.

The discussions were very fruitful.

The participants:

1. **renewed** their agreement with the general framework and feasibility of the IGMA5000 project, which is carried out under the aegis of CGMW and with the support of UNESCO and in line with the resolutions adopted during the 1st, 2nd and 3rd workshops;
2. **underlined** the high quality of the preparation of the 4th Workshop;
3. **expressed** their congratulations to Prof. Ren Jishun and his team for the achievements in the 4th workshop on the IGMA5000, warmly wish him to quickly recover a good health, and extended their sincere thanks to the China Geological Survey (CGS) and the CGMW S/C for South and East Asia for their organization of this meeting and to the Institute of Geology of the Chinese Academy of Geological Sciences (CAGS) for its warm welcome to Beijing and hospitality during the workshop;
4. **appreciated** the invited lectures on the regional geology of Asia given on October 24 and 25;
5. **expressed** their entire satisfaction at seeing, for the first time, the quadrangle of IGMA completely filled, with recent inclusion of the International Map of the Middle East (IGMME), and observed that adjacent areas were added: the North East Africa, part of Europe, part of Russian Arctic and North West Australia;
6. **required** that the areas outside those of the working groups be further reviewed by relevant specialists,

7. **were confident** that the Coordinator and his team and the six working groups will successfully complete the IGMA5000 project according to schedule for 2010;

8. **were informed** that an upgraded draft of the IGMA5000 will be presented at the next General Assembly of CGMW (Paris, February 2010) and that the final IGMA meeting to be held in 2011 is planned to be accompanied by a scientific international meeting on the Geological evolution of Asia where international specialists of the geology of Asia will be invited. A thematic symposium is planned for the next IGC (Brisbane, 2012) about the IGMA map under chairpersonship of Prof. Ren Jishun;

9. **were informed** by the editorial group that all complementary information to upgrade IGMA on time to be presented for the CGMW General Assembly next February 2010 in UNESCO, Paris has to be provided by the end of this year, to be integrated in the new draft of IGMA5000;

10. **discussed and adopted** the slight complements proposed to the legend (see in Annex) and attached document;

11. **were informed** that a new topobase has been prepared by Prof. Fan Benxian. They recall the previous resolutions (cf. 1st, 2nd and 3rd workshops) that, according to a general agreement, the geographic names on the topobase map relevant to each country will be adopted. Following resolutions 10 and 11 of the 1st IGMA-2006 workshop:*"10: the participants pointed out that special attention will be paid to cross boundary geographic names. Only those names which have been acknowledged by all the countries concerned can be adopted; and 11 : the participants asked to use English names for all geographical objects, such as lakes, mountains, peaks, seas etc."* ; a CD containing the files of the new map will be provided to each group to check, correct if necessary, and validate the geographical names, this information has to be provided before the end of the year 2009;

12. **authorship has to be ensured** by each working group in order to be printed on the lay out of the IGMA.; information have to be provided as soon as possible, and in any case before the end of this year in order to appear on the next draft of the IGMA5000; CGMW layouts will be provided to the editorial group in order to exemplify how the diverse contributions were acknowledged in recent CGMW maps;

13. **invite** Prof. Tran Van Tri to construct the database for Viet Nam, Cambodia and Laos according to the database format of IGMA5000 based on available published data and invite Prof. Tomurtogoo to cooperate with Chinese GIS experts to construct the database of Mongolia;

14. **were informed** that, following the resolutions adopted during the first meeting a book "Geology of Asia" will be prepared, based on the map; it is to be underlined that chapter one "Notes on compiling the IGMA5000" will also be edited as a booklet containing explanatory notes at the same time as the map;

15. The book "**Geology of Asia**" which is to be achieved jointly by the geologists from the countries participating to the IGMA5000 project **will be prepared** under coordination of Prof. Ren Jishun. A program for writing the book was proposed on page 22 – 23 (part One) of the Proceeding 2009 of the 4th workshop (Annex 2). During the discussion on the afternoon of October 25th, it was proposed that the stratigraphy, tectonomagmatic, metamorphic events and tectonic evolution be described according to large structural units. These units have to be defined prior to asking contributors to provide relevant information. Each working group is asked to provide the names of contributors for the book. A template will be given and instructions will be sent by Prof. Ren Jishun after this meeting.

16. **were informed** that in its series of pedagogic booklets, CGMW is preparing a booklet dealing with the geology of Asia coordinated by Drs. M. Pubellier and Jin Xiaochi for the next IGC (Brisbane, 2012);

17. **proposed** that a test of a reduced scale IGMA would be realized to ensure a large educational diffusion of the map;

18. **were informed** by Dr. M. Pubellier about the excellent relationships established between CGMW and OneGeology and the future availability of the CGMW 1:5M Maps on OneGeology portal with

possible further developments (harmonization of the respective 1:5M map databanks) leading to a seamless World geological 1:5M map;

Resolutions of the Working Groups

Working Group 1

19. **inform** that last changes on the IGMA5000 were achieved during the St. Petersburg meeting last October;

Working Group 2

20. **inform** that the 1st digital complete draft of the International Geological Map of the Middle East (IGMME – 2nd Edition 1: 5 Million) was presented during the CGMW meeting in Tehran last May 2009, thanks to the key support of the Geological Survey of Iran (GSI). Some corrections, namely for Iraq, have already been provided to Dr A. Saidi and integrated to the draft presented during this fourth meeting. Last corrections should be provided to Dr A. Saidi before 15th of December to be integrated to the International Map of Middle East (IGMME) and IGMA and presented at the next CGMW Bureau and the General Assembly;

Working Group 3

21. **have carried out** talks with the countries, except Myanmar, and these countries have provided necessary data. They expressed their understanding of the situation of Myanmar and hoped that Myanmar colleagues may provide the database before the end of this year;

Working Group 4

Inform that:

22. Geological Survey of India (GSI), on behalf of Group 4 countries, have already provided i) Topobase map; ii) Tectonic domain map; iii) Stratigraphic correlation chart; iv) Seamless geological map of both lithostratigraphic and structural layers of Southern Asia in Geodatabase format as desired by CGMW;
23. In order to fill the databank of the countries of Group 4 as soon as possible, a correspondence between the references used for the name of the polygons of the map of Group 4 countries and the IGMA codes is needed;
24. For the compilation of Indian shelf geology (lithology and major structures) and the offshore geology surrounding the Indian sub-continent, CGMW would get NGRI (India) to provide the maps and datasets to the scientific expert identified for Group 4 for integration and submission to CGMW;
25. interaction amongst members of Group 4 is the need of the hour for setting and verification of the data products being prepared for the SE Asia segment of project IGMA5000;
26. The National Organizations of all the participating countries of Group 4 should be encouraged to participate and contribute more effectively within the deadlines for successful completion of the project IGMA5000;

Working Group 5

The participants of Group 5:

27. **acknowledge** the progress of the database and map over the area of Group 5

New legend

28. **agree** on the proposal of a new legend, including the omission of the “rifted thinned continental crust” unit, except for some items specific to offshore regions e.g. “accretionary complex”;
29. **suggest** drawing thin symbols signifying thrust (such as sigmoid lines with triangle) oriented parallel to the plate boundaries, instead of using a rigid pattern. The attribute needs to be associated with these symbols;
30. **propose** the new term “Subduction Front” to replace “Benioff Zone”, and change the attribute colour from red to black and the thickness from thin to thick;

31. **propose** the removal of the point symbol over "seamount" and the contour of the plateaus;

32. **propose** the removal of the mineral assemblage assigned to the boxes "HP and UHP", namely "coesite bearing eclogites" in the new legend shown on p.4 (see attached document);

33. **propose** to test new colours for the Neogene and Quaternary volcanic rocks; dark brown for intermediate to basic volcanic rocks, and purple for the basic volcanic rocks (however, lighter than the colour referring to ophiolite);

Upgrade of the map and database during 4th workshop

34. **thank** the adjacent groups and acknowledge their suggestions for the improvement of the map;

35. after carefully checking and discussing the draft, **suggest** various corrections on lines and polygons, mainly in the offshore region;

Future work plan

36. **request** the coordinator Dr. K. Wakita to send the draft incorporating all corrections decided during the 4th workshop, to the members before the middle of November, 2009;

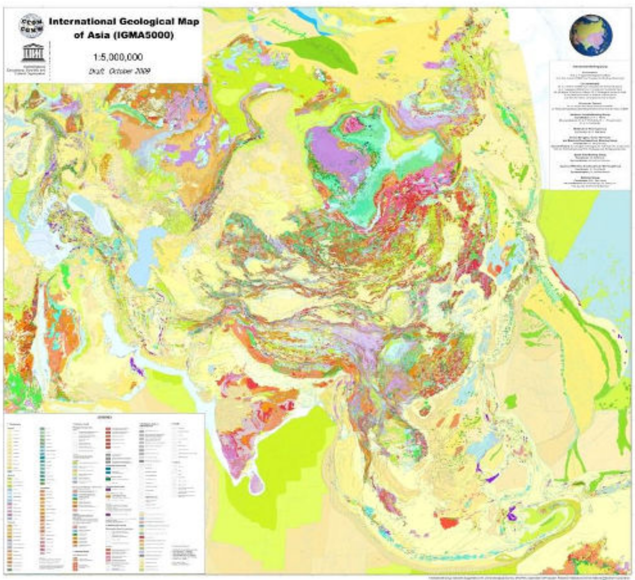
37. **agree** to validate, modify or add the modifications required, and return them to the coordinator before the end of November, 2009;

38. **request** the coordinator to submit the collected data before the end of December, 2009.

Annex and attached document IGMA 5000 modified legend

Complements to the IGMA 5000 legend

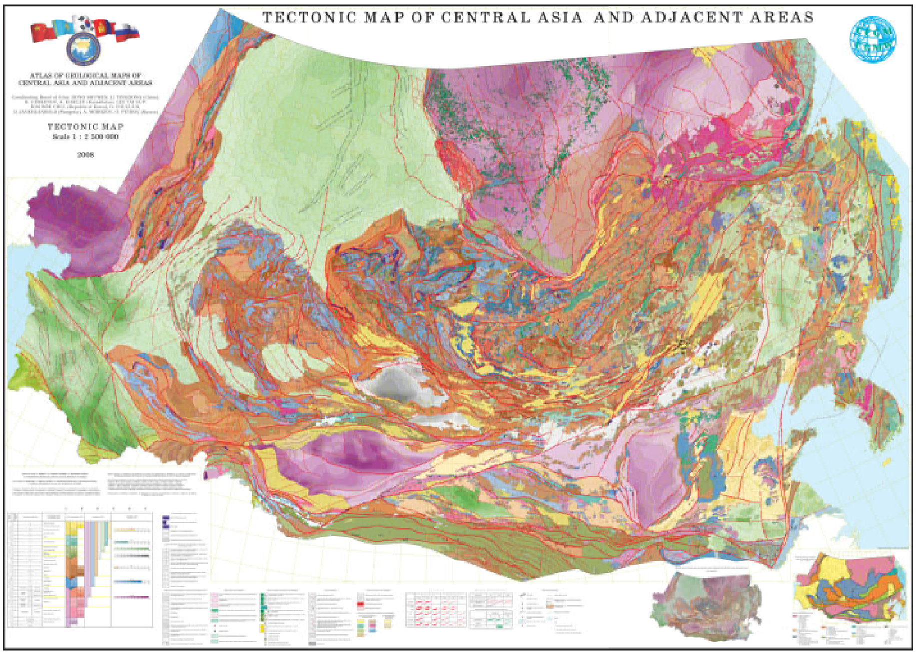
39. Some complements have been proposed to the legend of IGMA5000 (see attached document). Discussion on this proposition led to adopt the main part of these modifications, however:
    i) in the onshore legend, 1) the box "undivided volcanic rocks" could be named "undetermined volcanic rocks" 2) the box "granite" has to be used for undetermined compositions ranging from tonalite-granodiorite to monzogranite (granite s.l); 3) the box "charnockite has to be considered as hypersthene bearing granite (s.l). No distinctions are done for mangerite nor enderbite.
    ii) Plagiogranites have to be associated with ophiolitic complexes rather than with intrusive basic or ultrabasic complexes.



Draft of the IGMA map presented in the
4th Workshop in Beijing.

THEMATIC SUBCOMMISSIONS
SOUS-COMMISSIONS THEMATIQUES

TECTONIC MAP OF CENTRAL ASIA AT THE 1:2.5 M SCALE



The tectonic map of Central Asia and adjacent areas at a 1:2,500,000 scale was compiled in 2003-2007 by the Geological Surveys of Russia, China, Mongolia, Kazakhstan, and the Republic of Korea, under the aegis of CGMW Subcommissions for Northern Eurasia and for Tectonic Maps. The map clearly shows traces of interaction of two main types of tectonic process responsible for origination and reworking of the consolidated crust of Eurasia:

(1) deep mantle diapirism (intracontinental rifting);

(2) plate tectonic lithospheric geodynamics (spreading, accretion and collision). As a result of a combination of these processes, the granitic-metamorphic crust of Central and Eastern Asia formed.

The history of crust formation can be divided into six consolidation phases corresponding to the Paleoproterozoic through to the Late Mesozoic. Its reconstruction is based on the preserved geological complexes of paleooceanic, active and passive margin continental geodynamic settings. The tectonic map shows lateral and, partly, chronological changes of the accretionary Pacific style of structure evolution into the Indo-Atlantic style, typified by rifting and collision processes. As a result of multi-stage structural-thermal reworking, many seismofocal paleozones and paleosutures were repeatedly reworked and transformed into transcontinental strike-slip faults and shear zones accompanied by lateral movements of lithospheric masses, stress-metamorphism and intrusive magmatism.

Tectonic processes at a deep "mantle" level of continental rifting took place on the vast territories of Central and Eastern Asia and resulted in the formation of large magmatic provinces and areas of intraplate flood-basalt, alkali-basic, carbonatite, kimberlite, explosive breccia and other magmatic types. Each major phase of destruction and transformation of consolidated crust was accompanied by the formation of rift-related depression systems or extensive sedimentary basins. These phases embraced the following time intervals: beginning of the Mesoproterozoic, end of the Mesoproterozoic to the beginning of the Neoproterozoic, Cambrian to Ordovician, Devonian, end of the Permian to Early Triassic, Jurassic, Early Cretaceous and Cenozoic. The resulting central type magmatic structures and linear systems of rift-related grabens are clearly expressed in the modern topography of Central and Eastern Asia.

Taking into account the large size of the map, a reduced version was provided to CGMW by the editors.
This reduced version printed for the moment, is available on request at CGMW as inkjet printed copy (95x 50 cm)

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Jaeha Hwang, *Korean Institute of Geology and Mineral Recourses (KIGAM) (Republic of Korea)*

OneGeology

The One Geology project

OneGeology originated as a concept in the British Geological Survey in February 2006 and proposed at the CGMW General assembly of 2006, to support the initiative of the UN International Year of Planet Earth 2008 (IYPE) and the desire of many geological surveys to make a national contribution to IYPE that would have global impact. OneGeology is a voluntary initiative of Geological Surveys, supported by a number of global and regional bodies, in particular CGMW. OneGeology effectively became a project in March 2007 with the endorsement of the "Brighton Accord" by 81 participants from 43 nations.

The prime objectives of OneGeology are: to make geological map data accessible on the Internet, to accelerate the interoperability of geoscience data, and to share know-how and expertise in digital map web delivery. At a time when trans-national environmental problems, in particular climate change, have never had a higher profile, when so many geological surveys are being asked questions by their governments about their future role and contribution, when the web and digital systems are providing innovative global reach, and when many regional groups (for example the European Union) are establishing spatial data infrastructures, combining and sharing our experience and assets in this way would seem to be essential.

CGMW and One Geology

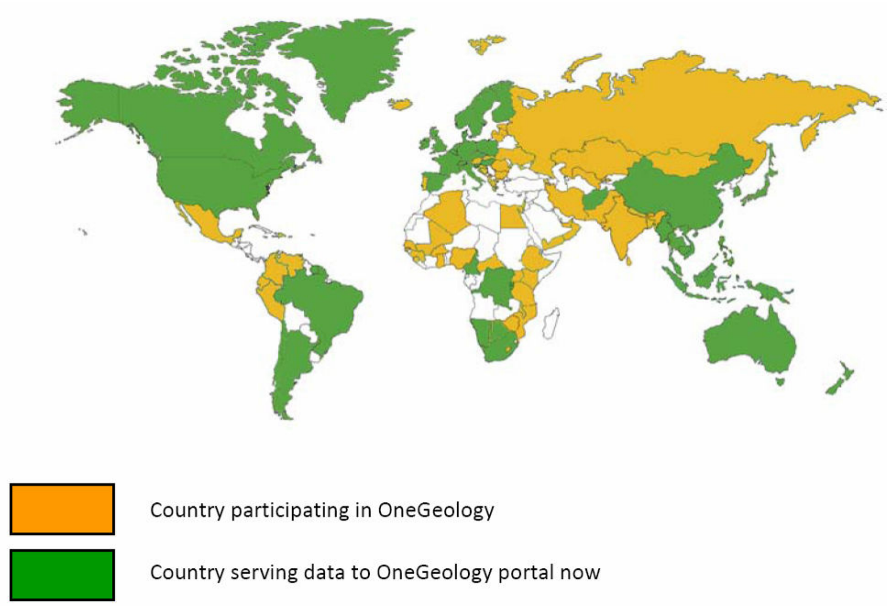
After being initiated at General Assembly 2006, the OneGeology project defined its goals

Since the prime objectives of OneGeology are not dedicated to compile nor design cross boundaries geological maps, it is therefore a good complement to CGMW.

As indicated by its name, the OneGeology project refers to 1:1M geological maps, while CGMW focus on global maps at the scale of 1:5 million in general, and at 1:2 million for specific areas of the world. Gradually, the maps of the Commission will be accessible at the OneGeology server. From the introductory layer of the Geological Map of the World at the scale of 1:25 million, it will be possible to zoom into greater scales up to 1:1 million.

Steering Group Meeting in Paris April 2009

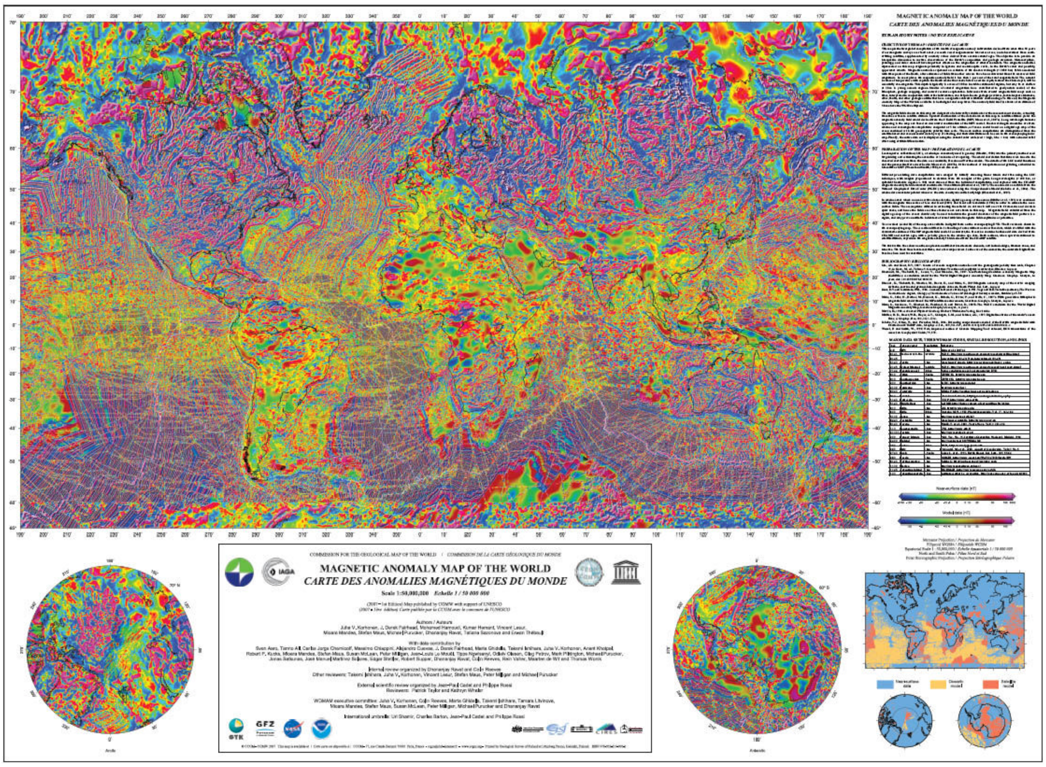
A total of eight members - 1 member to represent the Geological Surveys and Organisations within each of the 6 regions of the world (Africa, Asia, Europe, North America, South America, Oceania) and two representatives of UNESCO and CGMW. During this meeting it was proposed and acknowledged that CGMW, together with UNESCO, is now part of the Steering Group. Since then, IUGS joined also the Steering group.



www.onegeology.org

INTRODUCTORY NOTES OF
CGMW MAPS PUBLISHED IN 2007-2009

World Digital Magnetic Anomaly Map (WDMAM)



EXPLANATORY NOTES

OBJECTIVE OF THE MAP

This map is the first global compilation of the wealth of magnetic anomaly information derived from more than 50 years of aeromagnetic surveys over land areas, research vessel magnetometer traverses at sea, and observations from earth-orbiting satellites, supplemented by anomaly values derived from oceanic crustal ages.

The objective is to provide an interpretive dimension to surface observations of the Earth’s composition and geologic structure. Metamorphism, petrology, and redox state all have important effects on the magnetism of crustal materials. The magnetic anomalies represented on this map originate primarily in igneous and metamorphic rocks, in the Earth's crust and possibly, uppermost mantle. Magnetic anomalies represent an estimate of the short-wavelenght (< 2600 km) fields associated with these parts of the Earth, after estimates of fields from other sources have been subtracted from the measured field magnitude. In most places the magnetic anomaly field is less than 1 per cent of the total magnetic field.

The natural increase of temperature with depth in the Earth means that rocks below a certain depth, termed the Curie depth, will be essentially non-magnetic. This depth is typically in excess of 20 km in stable continental regions, but may be as shallow as 2 km in young oceanic regions.

Studies of crustal magnetism have contributed to geodynamic models of the lithosphere, geologic mapping, and natural resource exploration. Inferences from crustal magnetic fields maps such as these, interpreted in conjunction with other information, can help delineate geologic provinces, located impact structures, dikes, faults, and other geologic entities that have a magnetic contrast with their surroundings. To this end, the Magnetic Anomaly Map of the World is available in both digital and map form. The anomaly field itself is shown at an altitude of 5 km above the WGS84 ellipsoid.

The magnetic fields shown on this map are designed to be internally consistent over the measurement domain, extending from the surface to satellite altitude. Upward continuation of the data shown on this map to satellite altitude yields the magnetic anomaly field model derived from the CHAMP satellite (MF5, Maus et al., 2007a). Long-wavelength features appearing in the map are based on downward continuation of the MF5 model. Short-wavelength anomalies are from marine and aeromagnetic compilations computed at 5 km altitude, or from a model based on a digital age map of the ocean combined with the geomagnetic polarity scale. The near-surface compilations are distinguished from the satellite-based and oceanic model data by way of shading, and their distribution can be seen in the accompanying index map. Finally, the entire data set is displayed using the natural color scale (red = high, blue = low) with a shaded relief effect using artificial illumination.

PREPARATION OF THE MAP / PRÉPARATION DE LA CARTE

Least-squares collocation (LSC), a commonly used technique in geodesy (Moritz, 1980) was the primary method used for gridding and estimating the anomalies at 3 minutes of arc spacing. The model correlation functions were tuned to the observed correlations from the data over Australia, Russia and North America. The details of the LSC model functions and the process are described in Maus et al. (2007b, submitted). Other methods of interpolation and gridding, embedded in Geosoft or GMT (Wessel and Smith, 1998), were also used.

Different pre-existing data compilations were merged by initially removing linear trends and then using the LSC techniques, with weights proportional to distance from the margins of the grids. Long-wavelengths (> 400 km, or spherical harmonic degrees ≤ 100) were remove from the individual compilations, and replaced with the CHAMP magnetic anomaly field downward continued to 5 km altitude (Hemant et al., 2007). The marine data available from the National Geophysical Data Center (NGDC) was reduced using the Comprehensive Model (Sabaka et al., 2004. The marine data were interpolated whenever the data density was sufficiently high (Hamoudi et al., 2007).

In marine areas where there exists no near-surface data, the digital age map of the oceans (Müller et al., 1997, 2004) was combined with the magnetic time scales of Gee and Kent (2007) and Kent and Gradstein (1986) in order to estimate the near-surface fields. The assumptions utilized in estimating these fields do not work well over the Cretaceous and Jurassic quiet zones, and hence the fields over these features are not shown in this map. Magnetic fields calculated from the digital age map of the oceans should only be used to indicate the general character of the magnetic field pattern in a region, and may prove unreliable indicators of actual individual magnetic field amplitudes or polarities.

Two versions (A and B) of the map are available in digital form in the accompanying DVD. The B version is shown in the accompanying map. The A version differs in its handling of areas without near-surface data, which are filled in with the downward-continued CHAMP magnetic field model. In contrast, the B version contains both model data derived from CHAMP, and marine ages, with a priority given to the marine age data. Both versions, when upward-continued to satellite altitude, reproduce the magnetic anomaly field derived from the CHAMP satellite.

The thick white lines shown on the map locate undifferentiated tectonic elements, and include ridges, fracture zones, and trenches. The black lines locate coastlines, and a few major rivers. In the case of the Antarctic, the Antarctic Digital Data base has been used for coastlines.

MAJOR DATA SETS, THEIR WDMAM CODES, AND SPATIAL RESOLUTION

Code	Area covered	Res	Reference
13.0	MF-5	5 km	Maus et al. (2007a)
101.41 101.45	Marine track-line	variable	NGDC, http://www.ngdc.noaa.gov/mgg/geodas/trackline.html Interpolated (101.41) Non-interpolated (101.45)
121.43	Arctic	5 km	GSC, http://gsc.nrcan.gc.ca/index_e.php
131.45	Project Magnet	variable	NGDC, http://www.ngdc.noaa.gov/seg/geomag/proj_mag.shtml
171.44	Oceanic model	10 km	NASA candidate model, accompanying DVD
201.2	Africa	15 min	GETECH, http://www.getech.com/
201.2	S. America	15 min	GETECH, http://www.getech.com/
222.3	South Africa	5 km	SADC, http://www.sadc.int/
231.32	Botswana	5 km	http://www.gov.bw/
302.43	Antarctica	5 km	ADMAP, http://www.geology.ohio-state.edu/geophys/admap/
401.3	Eurasia	2 km	Geoscience Canada, http://gsc.nrcan.gc.ca/index_e.php
411.43	East Asia	2 km	CCOP, http://www.ccop.or.th/

421.43	Middle East	1 km	AAIME, http://home.casema.nl/errenwijlens/itc/aaime/
441.3	India	5 km	GSI, http://www.gsi.gov.in/
442.2	India	50 km	Qureshy, M.N., 1982, Photogrammetria, Vol. 37, 161-184
451.32	Japan	1 km	http://www.aist.go.jp/GSJ/
504.43	Australia	1 km	Geoscience Australia, http://www.ga.gov.au/
601.43	Europe	5 km	Wonik, BGR, http://www.bgr.bund.de/
611.3	Fennoscandia	5 km	GTK, http://www.gtk.fi/
621.321	Austrai	5km	http://www.geologic.ac.at
622.2	Canary Islands	5 km	Publ. Tec., No. 35, Instituto Geografico Nacional, Madrid, 1996
624.22	Finland	1 km	http://projects.gtk.fi/WDMAM/
625.2	France	10 km	IPGP, http://www.ipgp.jussieu.fr
626.2	Italy	5 km	Massimo, C. et al., 2000, Annali di Geophysica, Vol. 43, No. 5
627.43	Spain	1.5 min	Socias I., et al, 1991, Earth Planet. Sci. Lett., 105, 55-64
628.3	Russia		VSEGEI, http://www.vsegei.ru/WAY/247038/locale/EN
701.43	North America	1 km	NAMAG, http://pubs.usgs.gov/sm/mag_map/
711.32	Mexico	5 km	http://www.coremisgm.gob.mx/
811.45	Argentina inland	5 km	SEGEMAR, http://www.segemar.gov.ar/db/
812.3	Argentina margin	5 km	Ghidella, DNA, http://www.dna.gov.ar/

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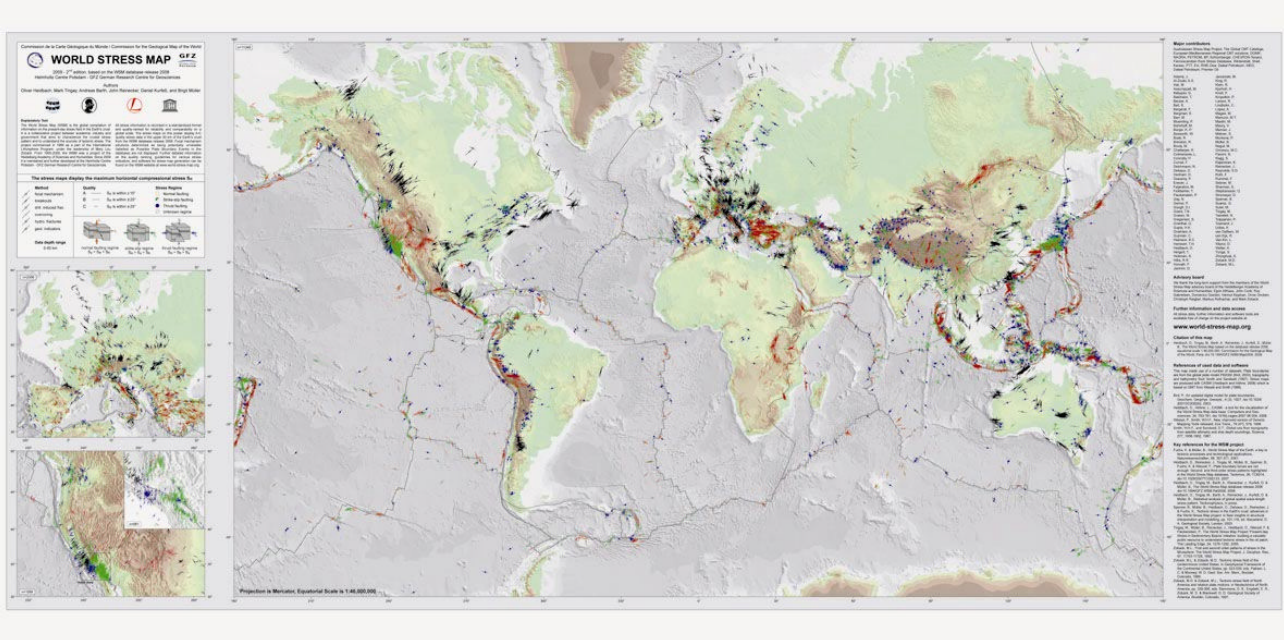
Mercator projection
Ellipsoid WGS84
Equatorial scale l:50,000,000
North and South Poles: Polar stereographic projection

WORLD STRESS MAP



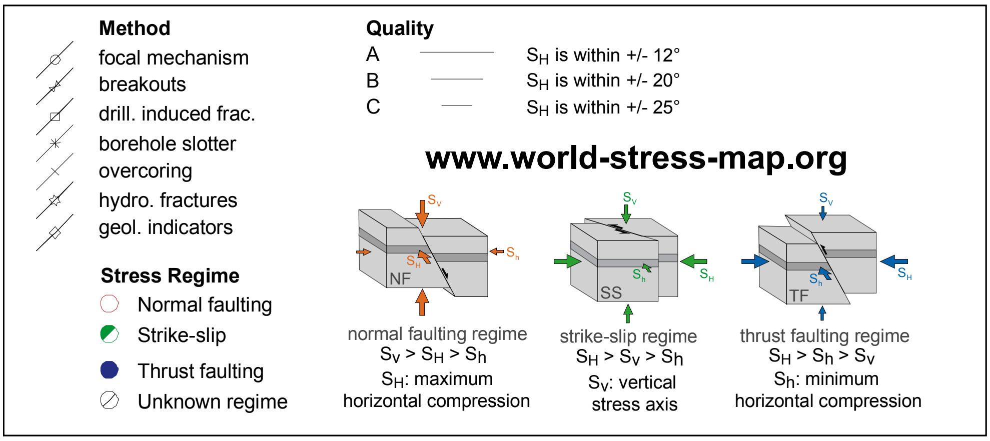
The World Stress Map (WSM) is the global compilation of information on the present-day tectonic stress field in the Earth's crust. It is a collaborative project of university, industry and governmental organizations that aims at understanding the sources of stress in the Earth's crust.
The project was initiated in 1986 under the auspices of the International Lithosphere Program under the leadership of Mary Lou Zoback. Since 1995 the WSM is a research project of the Heidelberg Academy of Sciences and Humanities and is located at the Geophysical Institute of the University of Karlsruhe in Germany.

The WSM database release contains 13,853 data sets derived from a wide range of shallow to deep stress indicators, including earthquake focal mechanism solutions, well bore breakouts, drilling-induced fractures, hydraulic fracturing, strain relief measurements, and young (Quaternary) geological indicators. To integrate stress data from different sources into one common database, standardized quality-ranking procedures have been developed for all stress indicators. This quality ranking guarantees reliability and global comparability of the stress data.

Each stress record is assigned a quality between *A* and *E,* with *A* being the highest quality and E the lowest. A-quality data indicate the maximum horizontal stress orientation (S_H) to be accurate to within – 15°, B-quality data accurate to within – 20°, C-quality to within – 25°, and D-quality to within – 40°. E-quality indicates data with insufficient or widely scattered stress information. More than 10,500 higher-quality *(A-C)* data sets are contained in the 2005 WSM release.

The WSM is now a key resource for scientists and engineers in both university and industry useful for understanding geodynamic processes, assessing seismic hazards and the stability of tunnels, and also for improving hydrocarbon production, safe subsurface disposal of waste and greenhouse gases, as well as geothermal power production.

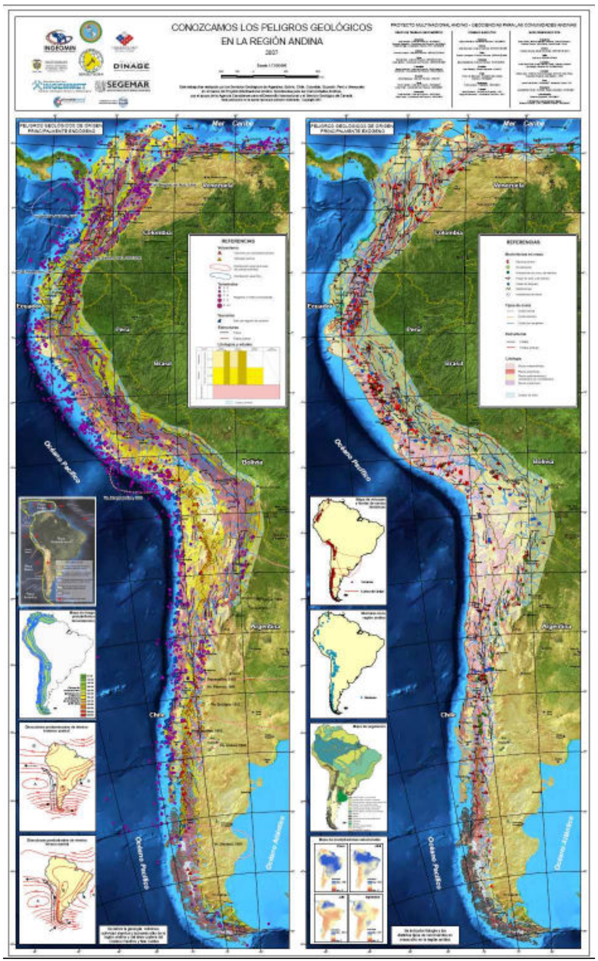
Further detailed information is available at http://www.world-stress-map.org . The WSM web site also includes regional stress maps, software, stress interpretation guidelines, and the fast online data base interface "*Create a Stress Map Online*" (CASMO). CASMO allows WSM users to create high graphic quality stress maps to their own specifications that are delivered to the user via e-mail within a minute.
For the visualization of the WSM database the orientation of maximum horizontal compressional stress is displayed in stress maps. Data selected for the World map are from the WSM 2005 release from all depth (0-40 km) and all A-C quality data records except single focal mechanism solutions labeled in the database as Possible Plate Boundary events (PBE) or within 200 km distance to oceanic spreading ridges.



Authors: O. Heidbach, K. Fuchs, B. Müller, J. Reinecker, B. Sperner, M. Tingay and F. Wenzel

Mercator projection
Scale at 1:46 000 000
54 x 120 cm + CD-ROM

KNOWING THE GEOLOGICAL HAZARDS IN THE ANDEAN REGION



The South American Geological and Mining Surveys under the Multinational Andean Project: Geosciences for the Andean Communities (MAP: GAC) have prepared a regional map of geological hazards of the Andean region, at a 1:7,500,000 scale. The map and the explanatory text were prepared by the Geological and Mining Surveys of Argentina, Bolivia, Chile, Colombia, Ecuador, Peru and Venezuela under the coordination of the Argentine Geological and Mining Survey (SEGEMAR).

The main purpose of this publication is to disseminate, with an educational perspective, the existence of geological hazards in the Andean region as well as the importance of the related geoscientific studies, addressed to non specialized public, using a simple language.

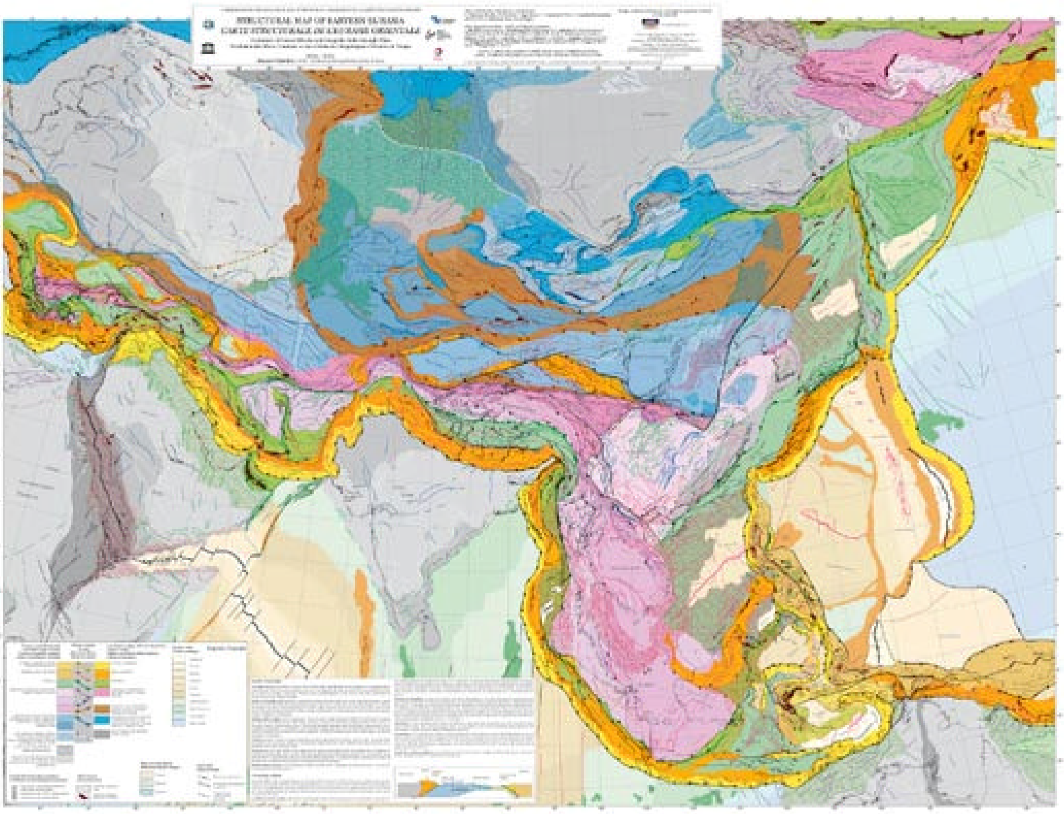
The map shows a compilation of main geohazards of endogenous (earthquakes, tsunamis and volcanic activity) and exogenous origin (landslides).

In the explanatory notes the geological processes that originate natural disasters are described, as well as the various factors that contribute or condition their location and development, such as the geology, the climate, the vegetation and the location of the population that can be directly affected.

The genesis and characteristics of each process is described, and examples of disasters of geological origin are presented for each Andean country. A highlight of the role of geosciences in the study, control, prevention and mitigation of natural disasters is also made.

Scale:1: 7 500 000
Published in 2007 + accompanying booklet in Spanish
Surface:104 x 84 cm
Proyecto Multinacional Andino
Printed by the Geological and Mining Survery of Argentina (SEGEMAR)

STRUCTURAL MAP OF EASTERN EURASIA



The map differs from, geologic, tectonic, and terranes maps, by emphasising on the correlation of the large belts of Eurasia. The units represented are not tectono-stratigraphic terranes but stable block v.s. deformed belts and accretionary wedge. The map is oriented toward a global legibility of the tectonic belts that contributed the continental growth of Eastern Eurasia.

Blocks and stable units represent continental crustal units which behaved as rigid units during major orogens and may constitute basement for sedimentary wedges. These units are separated by orogenic belts on the map, but do not represent a specific age. Hence, the cores of the main cratonic units formed during Precambrian times are represented, but also young crustal blocks or oceanic plateaus which caused shortening in orogenic wedges.

Wedges and orogens include modern and old accretionary wedges developped offshore in subduction zones and also onshore in fold-and-thrust belts. They represent products of subduction independantly of the oceanic or continental nature of the crusts involved. They mostly represent deformed belts of sediments, metamorphosed or not, nowadays overthrusted on continental crust. Orogenic wedges may also involve basement slivers of continental crust. In complex zones mostly in the Early Phanerozoic, orogenic belts have been much metamorphosed and may be considered “cratonized”.

Faults have been compiled and generalized and sorted by ages when documented. Options had to be chosen when information was not found, unclear, or contradictory. Many faults also have suffered reactivation and the colour asigned is that of the dominant event.

Sutures have also been temptatively sorted by age, but indeed may vary significantly along strike due to migration of docking. In ancient belts, due to erosion, they represent the crustal boundary of juxtaposed or overthrusted crust. Their location is approximative and may cross several alignment of ophiolitic bodies, implying that some are allochton, or result from the closure of complex arc/back-arc systems.

Metamorphic facies is only indicated by small coloured circles - indicating the dominant facies – in order not to obscure structural information.

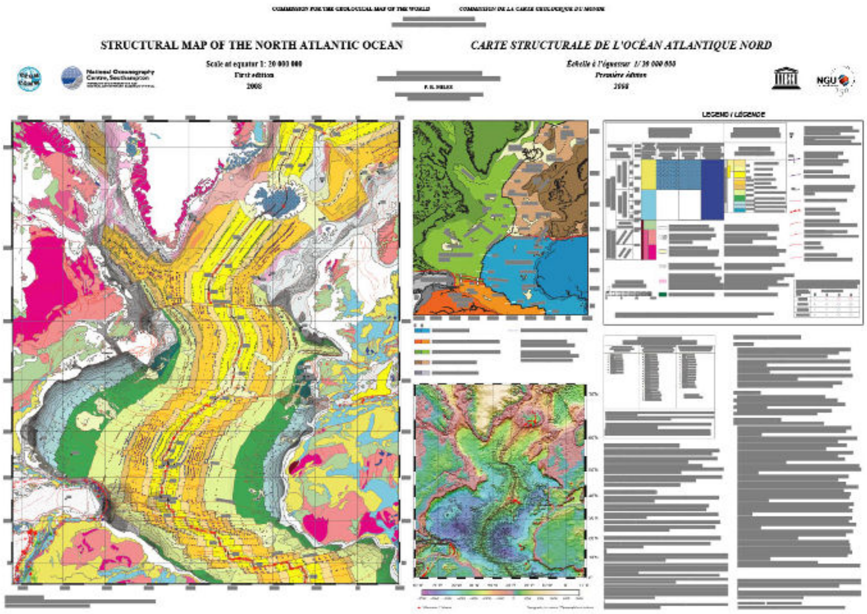
Main author: Manuel Pubellier (ENS/CGMW)
Equatorial scale l:12,500,000
©CGMW 2008
118 x 84 cm

Map on display at OneGeology portal
www.onegeology.org

THE MAP OF THE NORTH ATLANTIC OCEAN

Physiographic and Structural Mapping of an Ocean

GEOLOGICAL SYNTHESIS



ABSTRACT – *This* Map of the North Atlantic Ocean *synthesizes the interpretation of geological and geophysical data compiled from many oceanographic cruises undertaken over several decades. The main* **Structural Map** *includes the following parameters in the context of a simplified cartography of the onshore geology:*

- *The age of the oceanic crust (in Epochs), inferred from the identification of the geomagnetic reversal chronology.*
- *Picks of magnetic anomaly chrons where they have been observed or interpreted.*
- *Seafloor spreading axes, transform faults and fracture zones, anomalous relief and subduction zones, all contributing to the morphology of the ocean floor.*
- *Seaward Dipping Reflector volcanic sequences.*
- *The distribution of onshore and offshore earthquakes.*
- *The DSDP(IPOD), ODP and IODP drill sites that reached basaltic basement, with each site number.*
- *The contours of sediment thickness in oceanic and thinned continental crust areas.*
- *Crustal deformation zones*

The ***Physiographic inset*** *includes the bathymetry, multi-beam imagery and continental relief plus, recent or currently active volcanoes and meteoritic impact craters. This is shown with a corresponding* ***Geodynamic sketch*** *to describe the juxtaposition of the tectonic plates.*

FOREWORD

The Commission for the Geological Map of the World (CGMW/CCGM)) is a scientific Non-Governmental Organization (NGO) recognised as Category A by UNESCO and affiliated to the International Union of Geological Sciences (IUGS). It was initiated in an early form in 1881 during the 2nd International Geological Congress (IGC) held in Bologna. During the 1980s the CGMW co-published with UNESCO the maps of the five oceans of the globe for the first time (including the "Antarctic Ocean"). This was published as part of the *Geological Atlas of the World* printed at a relatively small scale. Two decades have elapsed, and our knowledge of the deep seafloors of the world has improved to such an extent that eight years ago the Commission decided to initiate a new series of seafloor maps featuring whole oceans.

The Map of the North Atlantic Ocean[1], issued for the 33rd IGC in Oslo in 2008, is the second one of this series, the Indian Ocean being the first. The publication of the map received financial support from UNESCO and the Geological Survey of Norway.

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[1] Authors of the maps: Peter Miles with the collaboration of B. Tucholke, C. Gaina, L. Gernigon, D. Müller, J. Ségoufin and GEUS.

MAPPING AN OCEAN

In an attempt to provide the most convenient synthesis of the main characteristics from an Earth science perspective, the design of a map of an ocean (rather than an atlas), is not as trivial an exercise as is at first apparent, particularly compared with onshore cartography. The reasons for this are:

- The map cannot be a truly geological, that is, describing the out- or sub-cropping formations as in land geology otherwise it would mainly represent Plio-Quaternary sediments.
- Neither is it possible to construct a tectonic map because of the specific evolution of the oceanic lithosphere whose age is never older than some 200 Ma.
- The map is also not simply the illustration of one geophysical parameter (seismicity, magnetic anomalies, spreading rate etc.) but a representation of all physical parameters, plus observed and interpreted lineations.
- The map needs also to include some contextual land geology relevant to the offshore areas (islands and surrounding continents), unlike the majority of maps devoted to an oceanic area. This provides complimentary information in understanding the evolution of an ocean basin, such as in the fit of adjacent Precambrian shields prior to rifting and separation of the continental fragments.
- Also the map cannot merely stack-up different entities of information as this would impede an acceptable balance between clarity and detail.

For all these reasons we chose to title this kind of cartography a "s***tructural map***", a term not heavily constrained by semantics.

As to the size of the printed map, our publishing experience led us to avoid too large a dimension owing to printing constraints, user convenience, display dimensions and cost. Therefore the final scale (1:20,000,000 at the Equator) corresponds to that of the Indian Ocean Map. The projection used is Mercator using the WGS-84 ellipsoid generally adopted by the offshore sciences community such as the International Hydrographic Organization and the Intergovernmental Oceanographic Commission. Consequently the northern boundary of the map was limited to 72° N in order to avoid too much distortion of the regions towards the Arctic, while retaining significant detail in the northern Norwegian-Greenland Sea.

Because of the legibility constraints the *Map of the North Atlantic Ocean* comprises a main Structural *Map* plus a Physiographic inset and an explanatory geodynamic sketch.

PHYSIOGRAPHY

It would have been difficult to compile even a few additional entities of information onto a single structural map without loss of clarity, let alone the detail involved with physiography. On the other hand, geophysical data bases allow production of high resolution computer generated images of the physiography of the Earth's surface and seafloor using colour shaded relief. These displays are derived from elevation and bathymetric data sets and provide increased information and aesthetic value. For these reasons it was considered necessary to present the physiography in the form of an additional inset on the sheet.

Over the physiographic background 4 additional data entities have been placed with due consideration for the quality of the relief image:

1. Selected fine-line **isobaths** at 200m, 1000m and then every 1000m.
2. All active or Holocene[2] (<10,000 yrs) **volcanoes**, all onshore, marked as a small red triangle. They represent the eruptive centres extracted from the Smithsonian online files (Washington D.C.). They are concentrated in the eastern Caribbean where the Lesser Antilles Island Arc contains 17 active volcanoes. The maps show the coincidence between these volcanoes and earthquake epicentres in this region. Other volcanic centres are at the Azores triple junction, Iceland and Jan Mayen island.
3. **Astroblemes**, or meteoritic impact craters, are marked as a small green inverted triangle; they have been selected from the Planetary & Space Science Centre database of New Brunswick University.
4. **Toponomy**, including a selection of cities, rivers and islands with the principal submarine features. The latter are named in accordance with the International Hydrographic Organization recommendations.

STRUCTURAL MAP

ONSHORE AREAS

The North Atlantic Ocean is the result of the break-up of the Pangea super-continent which began between what is now North America and Africa (north-central Atlantic) in the Early – Middle

[2] The beginning of the Holocene has recently (2004), been moved back to 11,500 years B.P. (International Commission on Stratigraphy).

Jurassic. This formed the Laurasian super-continent of North America and Eurasia. A second break-up phase occurred with the southern Gondwana minor super-continent dividing into four continents that led to Africa and South America separating from south to north. The final phase of the formation occurred when North America and Greenland broke with Eurasia to open the NW Atlantic and Norwegian Sea. The Atlantic and Indian Oceans continued to expand, closing the Tethys Ocean. Following this the African Plate changed direction from west to northwest towards Europe and South America began to move north. Interaction of these motions with those of the Pacific Plate and Caribbean Plate form the complex transform, trench and Subduction plate boundary of the Caribbean Plate which abuts the North Atlantic Ocean where the boundary between the North and South American plates is as yet undefined.

The onshore continental areas have been schematically represented by:

- Archean and Proterozoic (or undifferentiated Precambrian or Precambrian + Paleozoic) **cratonic areas**.
- **Phanerozoic** (Paleozoic to Present) **basins or platforms**.
- **Phanerozoic orogenic belts: Paleozoic**, (e.g. North European Caledonides and Variscan (Hercynian) of western and central Europe with the contemporaneous Acadian Appalacian in North America), **Mesozoic** (e.g. early Alpine) and **Cenozoic** (e.g. Pyrenean to late Alpine principally in Europe).
- The **Meso-Cenozoic volcanic provinces** which accompany the different stages in the evolution of the ocean.
    - *Well defined hot spot volcanism*: Iceland formed during the later phases of the formation of the North Atlantic and forms part of the “North Atlantic igneous province” in NW Europe and Greenland. Other hotspots are the Canary, Cape Verde and Fernando all generating oceanic archipeligoes
    - *Cenozoic subduction related volcanism* (cf. infra “Subduction zones”) shown by the Lesser Antilles Island Arc where the Caribbean Plate over-thrusts the subducting North/South American Plates beneath the Barbados accretionary sedimentary prism.
    - Unspecified volcanism, unrelated to clear geodynamic processes.
- The tectonic features are indicated by faults (normal, strike-slip, and unspecified), and first order thrusts.

OFFSHORE AREAS

MAGNETIC ANOMALIES AND AGE OF THE OCEANIC CRUST

When seafloor spreading lavas cool they ‘fossilize’ the direction and intensity of the Earth’s magnetic field at that time to generate linear, identifiable magnetic anomalies. These allow the dating of the basaltic oceanic crust accreted to the seafloor at spreading centres – the principle element in the geological mapping of an ocean - through use of a timescale of the geomagnetic reversal sequence. With this the identification of a number of characteristic magnetic anomalies makes it possible to map the seafloor age and measure the seafloor spreading processes. Crust of unknown age or of current different age interpretations, and crust of unknown type (oceanic/thinned continental) is shown in dark grey to differentiate from thinned continental crust.

Here the *chronostratigraphic* ages (epochs, using ICS geological colours) are used and not the geomagnetic ages (or “*chrons*” corresponding to the geomagnetic reversal chronology) as often displayed in geophysical texts. This is to maintain consistency with geological events (e.g. the K/T boundary). These chronostratigraphic (geological) ages of the oceanic crust have been obtained by interpolation between digitized magnetic anomaly picks of fixed age (Müller etal., 1997). It was also considered valuable to show the location of the principal magnetic anomaly picks used in this age calculation plus other recent picks that detail seafloor spreading better in some areas. In the legend a table provides the list of each standard anomaly (or chron, ‘C’) and its age, following the geomagnetic timescale of Cande & Kent (1995) from C1o (0.78 Ma) to C33o (79.08 Ma), and after Gradstein et al. (1994) for C34 (83.0 Ma). These picks are shown as small circles colour coded for each chron. As there is no single magnetic pick data set for the whole of the map area the anomalies are shown, consistently, in three sections:

1. *North of the Newfoundland-Azores-Gibraltar lineation* after Gaina et al. (2002) plus Müller et al. (1997) anomalies 13y to 34 y in the Newfoundland Basin and Iberian Abyssal Plain. Anomaly C20 is shown as C20o and C20y north and south of the match respectively. Also shown here are anomalies M0 and M3 in the northern part after Tucholke et al. (2007), Miles et al. (1996) and Russel and Whitmarsh (2003).

2. *Between the Newfoundland-Azores-Gibraltar lineation and the Fifteen-Twenty FZ* after Müller et al. (1997) and (1999).
3. *South of the Fifteen-Twenty FZ* after Müller et al. (1997).

The segments of the Pacific Ocean and Caribbean Sea are unmapped and shown stippled, except for related structures. The Mediterranean Sea shows a generalized mapping for context.

STRUCTURAL FEATURES

The following structural features have been mapped: *axes of oceanic accretion* (mid-ocean ridges) with full present day spreading rates in cm y^{-1}; extinct spreading axes in the Labrador Sea, Norwegian Sea and bay of Biscay; plus principal selected transform faults with their fracture zone extensions mapped from satellite gravity and published maps. Extensions to, and other, FZs can be seen from magnetic anomaly pick sequences.

ANOMALOUS SUBMARINE PLATEAUX

Bathymetric highs associated with anomalous volcanic basement (seamounts, 'aseismic' ridges, oceanic plateaux, features of uncertain or disputed origin and selected significant buried basement features) are shown in a pale yellow/green colour. Notable features include the J anomaly Ridge south of the Grand Banks, the Greenland-Iceland and Faeroes ridges and the Azores triple junction.

SUBDUCTION ZONES

The one subduction zone in this region is the Lesser Antilles Island Arc. Here the underthrusting and relatively cold oceanic crust of the North and South American plate(s) is progressively heated as it is forced down into the plastic asthenopheric mantle beneath the Caribbean plate. It becomes dehydrated and triggers partial melting of the overlying mantle material which provides the source of the magma that generates the island arc volcanoes. The active sedimentary deformation front of this subduction zone is marked by a red line with small solid red triangles (Casey Moore, 2000). West of this has built up the accretionary prism with the island of Barbados being the only emergent part. The subduction plate boundary underlies the Barbados Ridge and is shown with large red triangles. A subduction vector shows the orientation and convergence rate.

To the north of the arc the convergence translates into the Puerto Rico trench and onto a westerly strike slip system of faulting. To the south the convergence is translated into strike slip motion into the north of South America.

DEEP-SEA DRILL SITES

The deep-sea drilling sites occupied by the international scientific consortia of DSDP(IPOD), ODP, IODP are shown as black stars with their site identification number. Only those that reached basaltic basement or marginal thinned continental crust are shown. These drill-holes are important because the basalt sampled can be dated using radiometric techniques and sediment sampled immediately above the basement can be dated from their microfauna. In the latter case the age of the oceanic crust predates the sediment age. These samples permit control on the age of the oceanic crust and calibration of the magnetic anomaly timescale reversal sequences. These in turn validate the seafloor spreading hypothesis and role of plate tectonics in the evolution of the Earth as a whole.

SEDIMENT THICKNESS

Compilations of sediment thickness, principally from seismic reflection measurements, can be rare. However the North Atlantic Ocean probably has the best coverage. The NGDC world sediment thickness grid was used to construct 1km isopachs (lines of equal thickness) shown as dashed lines with an overprinted grey hue whose intensity increases between 1 and 15km. The thickest sediments occur along the continental margins with thick sediment fans seaward of the large river deltas and estuaries such as the St Laurence (Laurentian Channel) and Amazon.

There is also a large Barbados sedimentary accretion over 15km thick associated with the convergence of the tectonic plates. Here sediment is being taken from the descending oceanic plate and piled up along the plate boundary forming complex sediment structures, shear zones and methane hydrates.

ZONE OF OCEANIC CRUST DEFORMATION

East of the Lesser Antilles Island Arc coincident with the diffuse boundary between the North and South American Plates and the Barracuda Ridge is a region of deformation cause by adjacent compressional and tensional forces. Another region of deformation exists across the Azores – Gibraltar plate boundary between the Eurasian and Nubian Plates. These areas are shown overprinted with hatching and are associated with diffuse seismicity. They may also be zones of future rupture between the North and South American Plates in the west and reflect the complex tectonics along the south western Eurasian Plate margin.

CONTINENTAL MARGINS

The delineations used in this map should not be confused with the legal term 'extended continental shelf' used in the United Nations Convention on the Law of the Sea (UNCLOS). This is a political boundary constructed by the application of parameters laid down by the UNCLOS Article 76 that may use morphological and geological factors in specific contexts.

The continental margin represents that part of the continent situated beneath sea level. It includes both the outer continental shelf – more or less arbitrarily bounded by the 200m isobath – and a continental slope and rise that meets oceanic crust at an average of about 3000m water depth. In this map the slope is not always shown to include the full morphology *senso stricto*, but as a representation of its location bounding the shelf edge and outer banks. Sediment fans and extended continental rises are not included as slope where they would obscure sediment thickness contours. The continent-ocean boundary may also lie beneath the lower slope.

The shelf is shown in white generally without any other information while the slope is in a light blue/grey and can contain some structural information relevant to the ocean structure or rifting. It is also extended onto deeper shelf areas to highlight channels. As island arcs are built up from 'continental' crust their submarine areas are treated as slope.

An addition to this map is 'thinned continental crust'. This is to show, where possible, the relationship between continental crust thinned during rifting and full seafloor spreading oceanic crust, notably off Iberia and Newfoundland. It also appears with the continental blocks formed during the staggered tectonic evolution of the ocean (Rockall Bank, Jan Mayen and The Grand Banks). Thinned continental crust is shown as continental slope but with the sediment thickness shading included.

Also new is the representation of seaward dipping reflector (SDR) sequences compiled from various sources. Indicated by a pale red hue they are shown only where they exist beyond the shelf edge.

TRANSITIONAL CRUST

Notably, in the Newfoundland basin and Iberia Abyssal Plain are two regions of transitional crust shown in dark green. They are in fact regions of sub-continental lithospheric mantle exhumed between clear continental crust and normal oceanic crust that appears close to the time of the Aptian - Albian boundary (Tucholke et al., 2007; Sibuet et al. 2007). These regions are 150-180km wide and include the M series of magnetic anomalies in these areas shown as CM0 and CM3 on the map.

THE SEAFLOOR SPREADING RIDGES

The North Atlantic Ocean spreading centre – generically known as the Mid-Atlantic Ridge (MAR) – is also known as the Reykjanes Ridge between the Charlie-Gibbs FZ and Iceland, the Kolbeinsey Ridge north of Iceland to the Jan Mayen FZ and the Mohns Ridge to the north. It forms the boundary between the North American and Eurasian/Nubian Plates and that between the South American and Nubian Plates. The Ocean was created from different phases of spreading during the Mesozoic and Cenozoic Eras, and at different rates. This can be seen on the map by the width of the coloured strips located on either side of the ridge; these bands represent the area of oceanic floor generated by the ridge during the time of a geological stratigraphic Series or time Epoch (i.e. Upper Cretaceous) since the Jurassic Period. The thin black arrows that overprint the ridge axes give the spreading direction and are annotated with the full (combined) spreading rate.

OVERVIEW OF THE OPENING OF THE NORTH ATLANTIC OCEAN

The breakup of Pangea started the formation of the Atlantic Ocean with rifting during Early to Middle Jurassic time that separated Gondwana (South America, Africa and other southern continental masses) from Laurasia (North America and Eurasia). This formed a plate boundary between Tethys and the Pacific that established seafloor spreading by CM25 time (~154 Ma, Late Jurassic). Spreading was well established by CM21 time when incipient seafloor spreading began in the Caribbean to separate South and Central America.

Africa began to separate from South America in the south at CM11 time (~132 Ma, Early Cretaceous) when Iberia may have been moving as part of the Nubian Plate to open the Bay of Biscay.

Rifting then began between North America and Eurasia (Gibraltar – Rockall) and seafloor spreading may have started in the Tagus Abyssal Plain by CM3 time (~127 Ma, mid-Early Cretaceous), possibly the earliest identifiable anomaly in that region. After this, mantle exhumation developed in the Newfoundland basin and Iberia margin, the J anomaly Ridge and Madeira-Torre Rise formed and normal seafloor spreading resumed and migrated north to establish seafloor spreading by C34 (84 Ma, Late Cretaceous) and later into the Labrador Sea.

The Labrador Sea opened by C30 at the latest, although a C32 pick (~72 Ma, latest Cretaceous) is plotted from the data set in crust of unknown age. Spreading then extended to the west of Rockall by

C24 time (~53 Ma, early Eocene) to separate Greenland and Eurasia and then ceased in the Labrador Sea and Baffin Bay between C20 and C13 time respectively (43-33 Ma, mid-Eocene to early Oligocene) leaving strike slip motion in the Davis Straight. The new spreading centre between Greenland and Eurasia (Rockall), formed first along the proto Reykjanes and Mohns Ridges, and then by C13 time along a now fossil Aegir Ridge. The latter was abandoned by C7 time (~26 Ma, late Oligocene) when the Jan Mayen continental block separated from Greenland and spreading jumped to Iceland. During this time Iberia moved north to partially close Biscay and began to move with Eurasia.

The MAR is offset by fracture zones of various scale. These express the tectonic plates' motions on a curved Earth. They also play an important role in the circulation of deep-sea currents in that they form breaches in submarine ridges that normally would impede the circulation of bottom waters essential to maintain the climatically important, nutrient rich ocean circulation pathways.

SEISMICITY

Seismicity is an important parameter in the study of current regional geodynamics. It underlines the limits of the lithospheric plates (spreading axes, transform faults and subduction zones) and active intra-plate rifting. Earthquake epicentres are symbolized with open diamonds and are shown for both on and off-shore occurrences. The time interval used for the occurrences is from 1973 to 2006 in order to both represent activity and maintain clarity. Also to this end only 4 categories of earthquake magnitude have been selected for display, the symbol size increasing for magnitude ranges 5.0-5.9; 6.0-6.9; 7.0-7.9; 8.0 and greater. The 4 categories of focal depths are shown as colour coding of the diamonds for depths 0-35 km; 36-70 km; 71-300 km and 301-700 km.

As explained, these earthquakes are not distributed randomly, rather they define accurately the plate boundaries and faults. At the MAR seismicity is generated by tensional stress exerted by the injection of magma at the axis of the ridge (oceanic accretion). At transform faults the shear stress is caused from opposite movements along the fault between the offset ridge axes either side of the fault. Both these causes of earthquakes are generally shallow and of low magnitude.

There is a concentration of earthquakes along the Lesser Antilles Island Arc. This is the only active subduction zone in the North Atlantic Ocean and forms the boundary between the oceanic crust of both American Plates which is being under-thrust beneath the Caribbean Plate. Friction occurring at the sloping interface between the two plates produces the stresses that generate seismicity during their release, and features what is known as a "Wadati-Benioff zone" which in this region generates the whole range of earthquake magnitudes and focal depths.

Other earthquakes are seen to be associated with the east and west areas of crustal deformation – both associated with plate boundary adjustments. Also the Azores triple junction bathymetric high volcanic centre, associated with the MAR, shows some off axis activity.

GEODYNAMIC SKETCH

A Geodynamic sketch is inset to give an overview of the configuration of the plate boundaries within the North Atlantic region at the present day. Accretion vectors and main bathymetric features, including principal fracture zones are included in the toponomy. It identifies the major oceanic plateaux and shows significant seamount chains. The regions associated with each tectonic plate are colour coded and differentiate between oceanic and continental regimes. Isolated micro-continents, outer banks and thinned continental crust are shown in their continental context.

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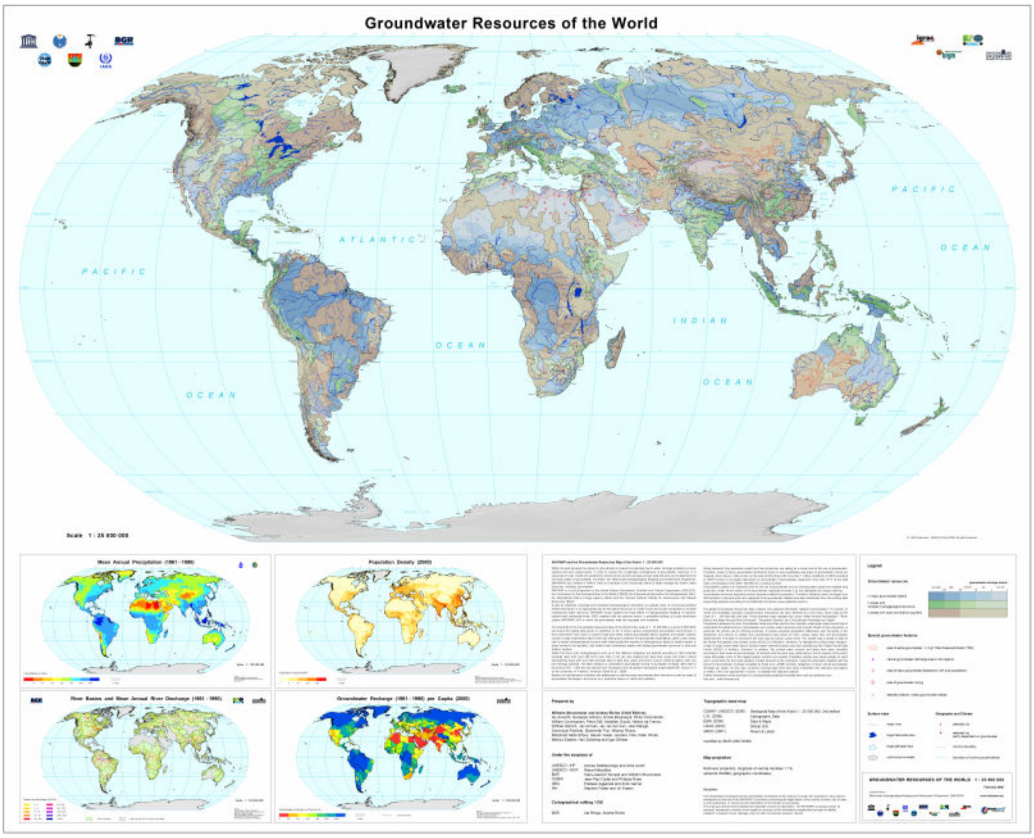
Mercator projection
Scale: 1:20,000,000
119 x 84 cm

GROUNDWATER RESOURCES THE WORLD



The Groundwater Resources of the World map at the scale of 1: 40 000 000 is the product of WHYMAP, a joint programme of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the Commission for the Geological Map of the World (CGMW), the International Association of Hydrogeologists (IAH), the International Atomic Energy Agency (IAEA) and the German Federal Institute for Geosciences and Natural Resources (BGR). This map combines the related data known or published so far, showing various characteristic groundwater environments in their areal extent:

- blue colour is used for large and rather uniform groundwater basins (aquifers and aquifer systems usually in large sedimentary basins that may offer good conditions for groundwater exploitation);
- green colour areas have complex hydrogeological structure (with highly productive aquifers in heterogeneous folded or faulted regions in close vicinity to non-aquifers), and
- brown colour symbolises regions with limited groundwater resources ln local and shallow aquifers.

The global Groundwater Resources Map contains only selected information related to groundwater. For reasons of clarity and readability important complementary information has been deferred to a set of four insert maps at the scale of 1 : 120 000 000). These thematic maps highlight the issues of "Mean Annual Precipitation", "River Basins and Mean Annual River Discharge", "Population Density" and "Groundwater Recharge per Capita".
See also: www.whymap.org

Map prepared by:

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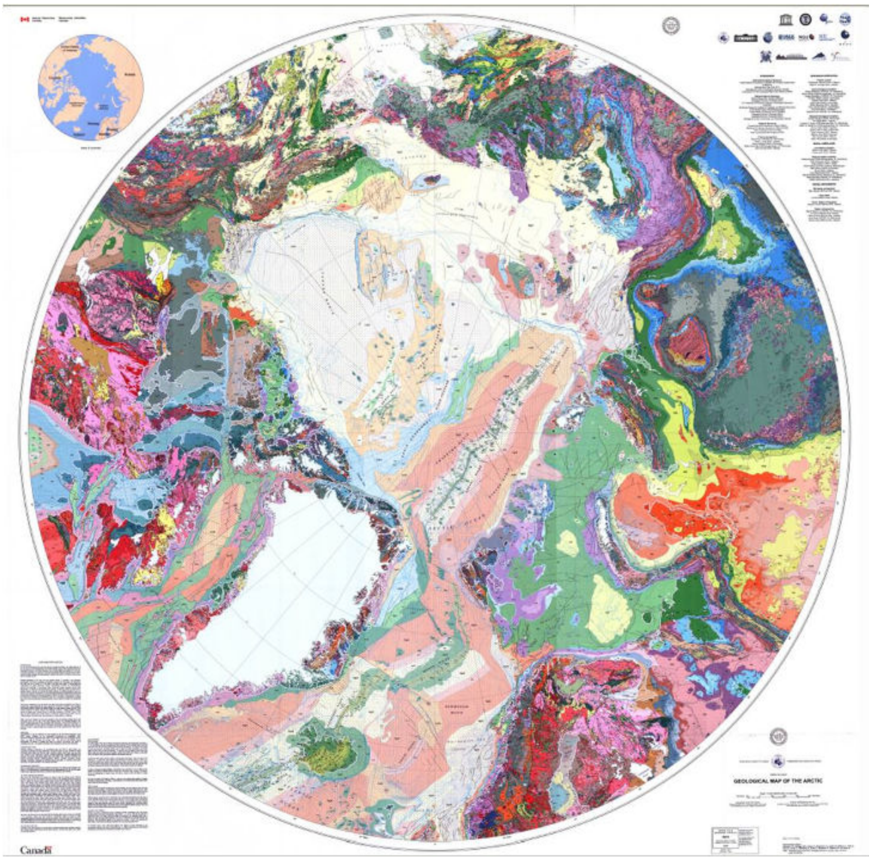
GEOLOGICAL MAP OF THE ARCTIC
at 1:5,000,000 scale



The *Geological Map of the Arctic* is a part of an international atlas of geoscience maps of the circumpolar Arctic. The 1:5 million scale *Geological Map of the Arctic* and its related database were developed by GSC teams based in Calgary and Ottawa with the active participation of scientific and technical staff from the geological surveys of Russia, the United States, Norway, Sweden and Denmark. Begun in February 2006 and carried forward at polar map workshops in Canada, Alaska and Russia, the final version of the Geological Map of the Arctic was published in paper copy and electronic forms in November 2008 as part of the International Polar Year.

La Carte géologique de l'Arctique *a été publiée par la Commission géologique du Canada (CGC) dans le cadre de la préparation d'un atlas international de cartes géoscientifiques de l'Arctique circumpolaire. La* Carte géologique de l'Arctique à l'échelle de 1:5 million*, et sa base de données associée, ont été élaborées par des équipes de la CGC de Calgary et d'Ottawa avec la participation active du personnel scientifique et technique des commissions géologiques de la Russie, des États-Unis, de la Norvège, de la Suède et du Danemark. Entreprise en février 2006 et prévue au programme d'ateliers sur la cartographie polaire tenus au Canada, en Alaska et en Russie, la version définitive de la* Carte géologique de l'Arctique *a été publiée sur papier et en format électronique en novembre 2008 dans le cadre de l'Année polaire internationale.*

Map prepared by:
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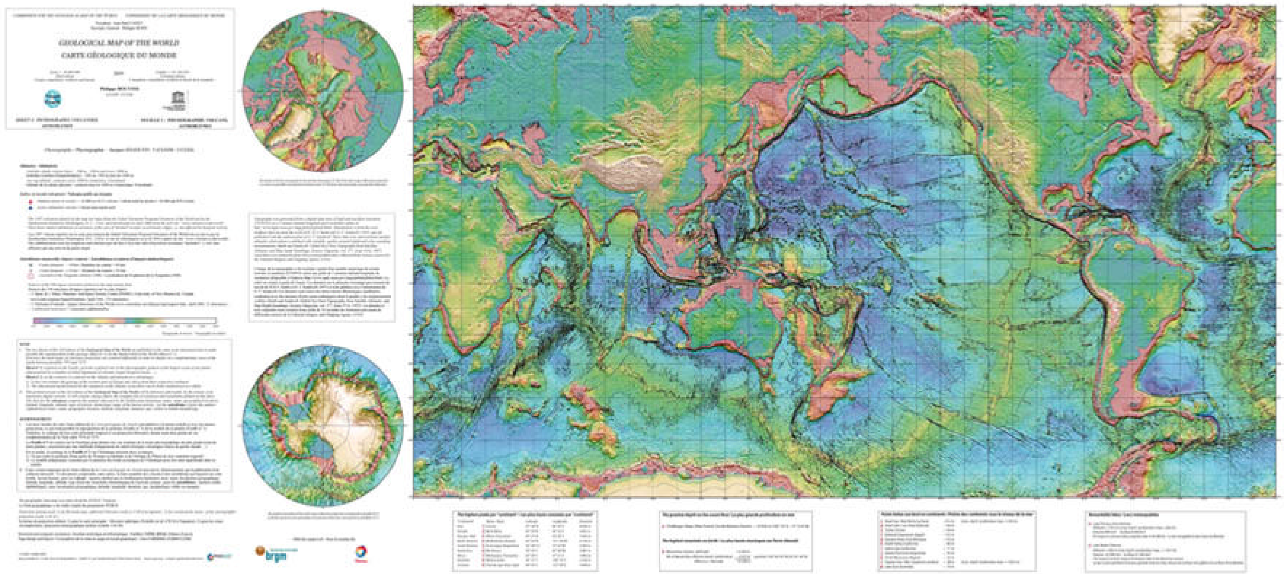
Printed version:
Main map + 4 legend sheets / 142 x 141 cm each

GEOLOGICAL MAP OF THE WORLD AT 1:50 000 000, 3rd edition

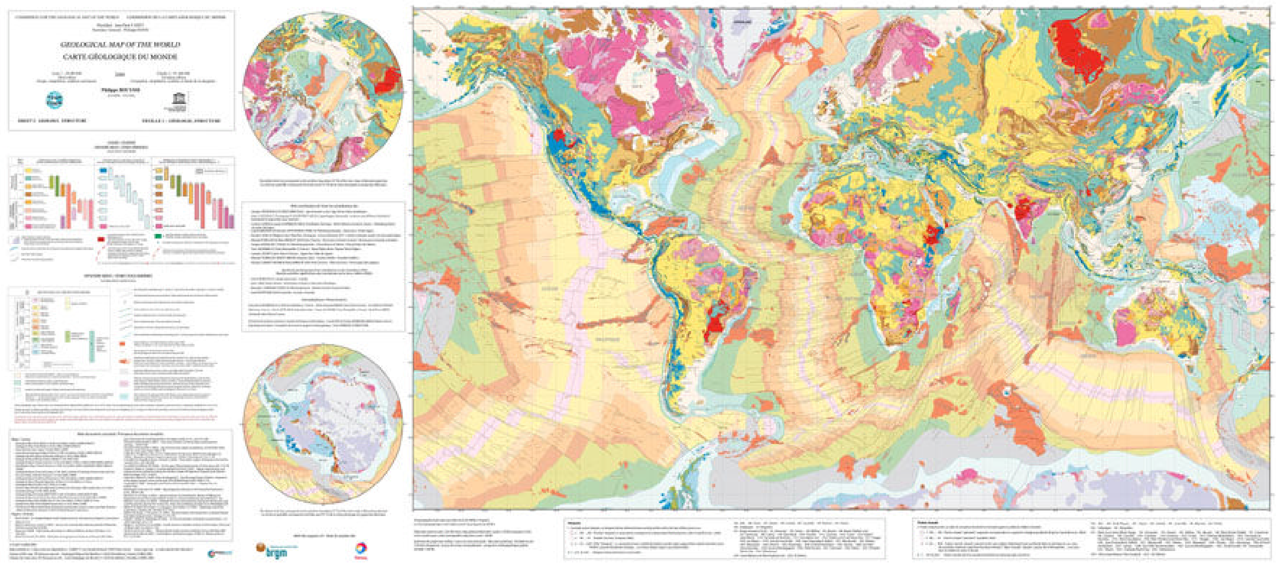
CARTE GÉOLOGIQUE DU MONDE A 1/5 000 000, 3e édition

Explanatory Notes / *Notes explicatives*

by/*par* Philippe Bouysse



Sheet 1: ¨Physiography, volcanoes, astroblemes



Sheet 2: Geology and structure

Maps available at www.ccgm.org
Surface of each sheet: 125,5 x 58 cm
Price: 10 Euros per sheet

Foreword

These Notes presented in a somewhat heterogeneous manner, combine regular peer-reviewed information dedicated to geoscience professionals – normal users of geological maps – with more basic information intended for the wider public including high school and college students who constituted a large section of the users of the former editions of this map.
It was not possible to address in these notes all the geologic, structural or geodynamic aspects that may be raised by the careful examination of the Map. The text, consisting mainly of comments on the legends, is aimed at shedding some light on a selection of examples that are, in our view, illustrative of each element of the Map.
It should be noted that, in this new edition, a particular attention was given to the oceanic areas, the large magmatic events, and to the geodynamics.

INTRODUCTION

This third edition of the *Geological Map of the World at the scale of 1:50,000,000* (1:50 M) follows the first and second editions published by the CGMW respectively in 1990 and 2000. This bilingual document (English-French) is the result of a highly synthetic compilation given both the small scale of the map and its educational purpose. It is a tentative and (very) simplified representation of the entire solid surface of our planet and includes both continental and oceanic domains.

This new edition is a **completely revised concept** compared to the map issued in 2000 and takes into account the state of the geologic knowledge at the turn of the century. For the first time, the Map is designed in two sheets of the same size:

- **Sheet 1 (Physiography, Volcanoes, Astroblemes)** revealing the fine-grained texture of the totality of the Earth surface when removing the water of the oceans.
- **Sheet 2 (Geology, Structure)** showing the distribution of the main chronostratigraphic units and the main structural features that make up the mosaic of the present-day surface of our planet, the result of 4.56 billion years[1] of unremitting "resurfacing". Sheet 2 is the equivalent of the single sheet of the second edition, notably reworked and extended.

Each sheet consists of a main map in Mercator projection, with the 2 polar areas in polar stereographic projections. The drafts have been carried out at the 1:25,000,000 scale (1:25 M).

The Mercator projection has only a true scale representation along the equator but allows an optimal visualization that does not favour the continents at the expenses of the oceans or vice-versa, unlike many other projections used for world maps. The main drawback of Mercator comes from the deformation that increases with the latitude to become infinite at the poles. For this reason, in this edition, the "upper" and "lower" latitude limits have been set at 72°N and 72°S for Sheet 2 (instead of 78°N and 65°S for the former two editions), and at 72°N and 70°S for Sheet 1. As a consequence, a large extent of the Antarctic continental coastline is visible, with a better delimitation of the southern ocean. As for Greenland, only its southern half is visible. On the other hand, the Taymir peninsula has been severed from the far north of the Eurasian continent.

The circum-polar projections extend to the 60°N and 60°S parallels (instead of 70°N and 60°S for the previous editions), Greenland is now displayed in its entirety and the 2 circum-polar areas have the same surface area. Their scale was slightly enlarged to 1:46 M.

For practical reasons and marketing policy, this 3rd edition at the **scale of 1:50 M** (for the Mercator projection) precedes the publication at 1:25 M (original scale of the draft). An interactive digital version of the Map is scheduled for the end of 2010.

In the previous editions at 1:25 M scale, the Mercator projection was printed in two parts (20°W-170°W; 170°W-20°W) that allowed adjusting the center of the Map either on the Atlantic (opening of an ocean and fit of the conjugated continents), or on the Pacific (subductions and hotspots tracks). In this new edition, the single 1:50 M sheet forced us to make a choice for the centering. In order to overcome these inconveniences, we decided to center Sheet 1 (Physiography) on the *Pacific* (meridian 0° for E and W sides) and Sheet 2 (Geology) on the *Atlantic* (180° meridian for both sides). This enables the reader to visualize both options of assemblage.

Scales and projections being identical, it is easy to superpose the morphological features of the offshore areas (Sheet 1) with the geological structures mapped on Sheet 2 using an illuminated table.

Nota: In the text that follows, words typed in bold characters correspond to the different items of the legends.

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[1] The abbreviation for *billion years* (10^9 years) is **gA** (from *giga-annum*, official designation of international geological bodies). The author wonders why the accusative form "annum" was chosen instead of the nominative one "annus".

SHEET - 1: PHYSIOGRAPHY, VOLCANOES, ASTROBLEMES

I.1- PHYSIOGRAPHY

Published for the first time by the CGMW, this Map displays all of the Earth's morphology and, in particular, the lesser known domains of the submarine areas that represent nearly 71% of its surface. Colour palettes are used to represent the land topography and, *ocean bathymetry, the latter including* fine black lines to indicate depth contours (**isobaths**) at every 1000 m. In order to avoid blurring of the physiographic perception of mountain chains, the equivalent for the subaerial areas (isohypses) were not plotted, except for the Greenland and Artarctica ice caps.
The topography was generated from a digital database of land and sea-floor elevation (EOTPO2) on a 2-minute latitute/longitude grid resolution. Seafloor data are from the work of *W. Smith & D. Sandwell* (1997). These data were derived from satellite altimetry observations combined with carefully quality-assured shipboard echo-sounding measurements. Land data were primarily from 30-second gridded data collected from various sources by the *National Imagery and Mapping Agency* (USA).
The compilation of altimetry data was carried out by our late colleague Jacques Ségoufin, who passed away on 8 September 2008 before the release of this Map[2].

I.2- VOLCANOES

On this Sheet are also plotted **1506 active or recent volcanoes or volcanic fields** that, *a priori*, cannot be considered as definitively extinct (i.e. having erupted during the last 10,000 years, corresponding to the Holocene epoch). These volcanic systems exist in 1436 **subaerial edifices** (**red triangles**), and 70 **submarine volcanoes** (**blue triangles**) as, for example, the Graham volcano (called also Julia or Ferdinandea) located near the southern coast of Sicily. All triangles are bordered by a fine white line that allows differentiation between each volcano in very active regions, such as in the island arcs (e.g. Sunda Islands) or in arc cordilleras (e.g. Andes). Consequently volcanic gaps are visible in some arcs such as that stretching all along 1500 km from the south of Ecuador to the south of Peru.
These volcanoes were extracted from the *Global Volcanism Program* of the *Smithsonian Institution* catalogue (as at March 2006) in their web site : *www.si.edu/world/gvp/* .
The fissure volcanism that characterizes the active mid-oceanic ridges (where the divergence of the lithospheric plates takes place) is not included here. It is however represented by the **axis of active accretionary ridge** (**red lines**) drawn in Sheet 2 of the Map.

I.3- ASTROBLEMES

Except for one site adjacent to Chesapeake Bay, **198 onshore astroblemes**, or meteoritic impact craters, are plotted on the Map. They are divided into 2 categories of crater diameter: < 10 km and ≥ 10 km, shown as small and large **black asterisks** respectively**.**
Data acquisition dates back to April 2006. The sources are:
1/ *Planetary And Space Science Centre* of New Brunswick University (John Spray & Jason Hines, web site : www.unb.ca/passc/Impact.Database) with 174 structures;
2/ *Jarmo Moilanen*, Finland: Impact structures of the World with 21 structures;
(site : www.somerikko.net/old/geo/imp/impacts.htm);
3/ *NASA/Goddard Space Flight Center Scientific Visualization Studio* for the Araona/Iturralde crater (Bolivia), not validated yet;
4/ Wade S. *et al., in* Lunar and PlanetaryScience, 2002, XXXIII, for the Velingara crater (Senegal);
5/ Paillou Ph. *et al.*, *in* C. R. Géoscience, 2004, v. 336, for the Gilf Kebir structure (Égypte).
Even though it is not an impact crater *stricto sensu*, the location of the Tunguska (Central Siberia) airblast of an asteroid (a comet?) in 1908 was identified with a red circle.

I.4- ADDITIONAL INFORMATION

This Sheet also includes information concerning the elevation of some specific locations:
The highest elevations (in meters) are indicated for each continent. It is noteworthy that in the particular case of Mount Elburs (at 5642 m, the highest peak in the Caucasus range), it is often that taken as the geographic boundary between Europe and Asia. Also the Puncak Jaya (4848 m) in New Guinea, and geologically part of the the Australian continental ensemble, surpasses the highest point of Australia, Mount Kosciusko.
A selection of the lowest points onshore, but below sea level, are shown. These include the surface of the Dead Sea (at -412 m, presently in the process of drying out if no drastic measures are taken) a salt lake whose bottom is at 742 m under the mean ocean level!
Two other lakes with remarkable characteristics that set world records are:
- Titicaca, on the Andean Altiplano is the highest navigable lake (+ 3810 m; maximum depth of 284 m).
- Baikal, in Siberia is the deepest lake in the world (1642 m beneath its surface which is at + 456 m of altitude). It also contains the largest deposit of fresh liquid water on the planet's surface (23 000 km^3).

[2] A former researcher at the Institut de Physique du Globe of Paris, he was Secretary General of the CGMW *Sub-commission for Seafloor Maps* from 1983 to 2004.

The lowest point in the ocean is located in the south of the Mariana subduction trench (– 10 920 m, in the Challenger Deep).
Finally, the highest mountain on Earth is not Everest (+ 8848 m), but the volcanic island of Hawaii (Big Island) with a total height of 10 239 m, if the elevation of its highest peak, the Mauna Kea volcano (+ 4206 m above sea level) is added to the maximum depth of its submarine bottom (– 6033 m).

SHEET - 2: GEOLOGY, STRUCTURE

II.1- ONSHORE AREAS

II.1.1- Chronostratigraphic units

The onshore areas represent 29,2% of our planet's surface and correspond mainly to the rock formations of continental origin (or continentalized in the case of island arcs). They are classified using **8** broad **chronostratigraphic units**[3]: 1 = *Cenozoic*; 2 = *Mesozoic*; 3 = *Upper Paleozoic*; 4 = *Lower Paleozoic*; 5 = *Neoproterozoic*; 6 = *Mesoproterozoic*; 7 = *Paleoproterozoic*; 8 = *Archean.* A number of regroupings were made when necessary by the geological or cartographic contexts. In comparison with the previous edition, and for the sake of coherence, the Quaternary and the Triassic Periods within the Cenozoic and Mesozoic eras respectively have not been shown individually. Also the 3 eras of the Proterozoic Eon have been introduced as units 5, 6 and 7.

Within these time units **3** main **lithological facies** ensembles were distinguished: • sedimentary formations or those of an undifferentiated nature (uneasy to define); • extrusive volcanic formations (**V),** corresponding to subaerial magmatism; • endogene formations (**P**), representing rocks originating in the Earth's interior at depth and having undergone significant metamorphism or that correspond to plutonic magmatic rocks). The last two rock categories are illustrated by a scattering of **superimposed dots** (**blue** for extrusive, **red** for the endogenous).
One exception was made for the **Cenozoic volcanism** (**V1**) that is identified by a uniform strong blue hue. Actually, the volcanism of this era (which includes Quaternary and Present times) is, in many cases (e.g. subduction volcanism), the consequence of on-going geodynamic activity. It is therefore important that this volcanism be seen in relation to the "active" volcanoes of Sheet 1 .

Another exception was also made for the oldest formations, the **Archean** ("8", older than 2,5 billion years/**gA**), as here they are not differentiated for the sake of simplification. It should be noted that the largest Archean outcrops are located in Canada.

II.1.2- Ophiolites

The ophiolites are remnants of oceanic crust (in increasing depth: submarine basalts, gabbros, peridotites) which, in a final phase of *subduction* following the collision of two continental blocks (or continentalized in the case of island arcs), escaped from their usual recycling within the Earth's mantle to become exposed inside mountain chains. They are the evidence of a "lost ocean" (Jean Aubouin) and punctuate large *suture* zones.
They can also be the product of an *obduction*, as in Oman, where a slice of oceanic lithosphere overthrusts the edge of a continental basement.

At the scale of the Map the extent of the ophiolitic formations (**bright green** hue) is relatively small and quite often hardly visible. The ophiolites plotted on this map are restricted to the Meso-Cenozoic times (older than 250 million years[4]). Particularly noticeable are the ophiolites of the Alpine arc, the Dinarides/Hellenides, the Zagros (Iran) and the Himalayas.

As an example of an island of ophiolitic origin, it is worth mentioning the tiny Gorgona island located on the continental Pacific margin of Colombia. Also Macquarie island (some thousand kilometers to the SSW of New Zealand) is the result of a *tranpressive* motion along the large dextral transform fault (see note 16) that separates the Indian Ocean (Indian-Australian plate) from the Pacific Ocean (Pacific plate) and uplifted a slice of Cenozoic oceanic crust. Also we note **Zabargad** island (formerly called St. John island) in the Red Sea (Egypt), known since Antiquity (Egyptians, Greeks and Romans) for its peridotite intrusion containing beautiful olivines (marked by a **green asterisk**).

II.1.3- Large igneous provinces: the traps

During some periods in the history of our planet large eruptive pulses of a relatively short duration (in some cases less than 1 million years) occurred in the Earth at mantle depth. These magmatic "crises" led to the vast and voluminous outpouring of basalts at the surface of the continents (**traps**) as well as on the ocean floor (**oceanic plateaus**). These

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3 i.e. geologic time slices. In the corresponding legend's table as well as in the oceanic crust ages (cf. II.2.2.1), the dates indicated are those validated by the International Commission on Stratigraphy in the *Geologic Time Scale 2008* published in 2008. The margin of error (2σ) was not mentioned for the sake of simplification.

4 The abbreviation for *million years* (10^6 years) is **Ma** from the latin "mega-annum", see note 1.

huge lava flows are interpreted as the consequence of the ascent of a large mantle plume up to the base of the lithosphere to produce the head of a strong "hotspot", during the first phases of its life (cf. II.2.2.7 et II.3). These surface features are labelled "**Large Igneous Provinces**[5]**"** (abbreviation **LIP**). The lavas of the traps, very fluid, are also termed "flood basalts".

In the former editions of this map the traps were merged into the too large time slices used to corresponding to the chronostratigraphic units of the legend (e.g. Upper Paleozoic for the *Siberian* traps, or the Mezosoic for the *Deccan* ones in India). On the other hand, a number of traps straddle the large main stratigraphic boundaries of these units, e.g. Upper Paleozoic/Mesozoic (250 Ma) in Siberia; Mesozoic/Cenozoic boundary (65.5 Ma, also called K/T boundary[6]) for the Deccan event. This might not be coincidental since, for a number of geologists (e.g. Courtillot and co-workers), the great *mass extinctions* that affected a number of living species[7] might be due to massive gas and noxious aerosols produced by these cataclysmic eruptions. This hypothesis is however in competition with (but also later associated to) the big meteoritic impact hypothesis, exemplified by the Chicxulub crater in the north of Yucatan in Mexico, for the K/T limit (see Sheet 1).

In order to deal with these issues, we chose for this new edition to assign the same color (**bright red-orange**) to all the **traps**, with an indication in black of their average age in **Ma** (e.g. "16 Ma" for the *Columbia River/Snake River* traps in north-west USA). It is to be noted that the *Parana* traps in southern Brazil have the same age (133 Ma, earliest part of Cretaceous) as the less extensive *Etendeka* traps in Namibia. Initially, these two features formed a single entity, but are now separated by several thousand of kilometres of ocean floor. They were originally produced by the Tristan da Cunha "hotspot" (identified as HG in the inset at the bottom of Sheet 2) and separated during the opening of South Atlantic which started shortly after, during the Early Cretaceous. Not too far from the Etendeka traps exists another slightly older ensemble of traps (183 Ma, Early Jurassic), the *Karoo*, that outcrop in southern Africa and were subsequently dismantled by erosion. The third large "LIP" in Africa are the *Ethiopian* traps (30 Ma, Oligocene) including also those of SW *Yemen* that are only separated by the narrow entrance of the Red Sea (Bab el Mandeb straits). Almost coeval with the Karoo traps, the remnants of the *Ferrar* traps (175 Ma) are associated with the sills of same age (marked on the Antarctic Polar projection by a **red asterisk** of the same color as the traps). These are scattered along the large Transantarctic Mountains range. The temporal and geographic proximity of these two ensembles, when part of the Gondwana supercontinent, might indicate that they were generated by the same hotspot. Two small traps located to the NE of the Deccan traps do not belong to the latter; in the NE corner of the Indian shield is the *Rajmahal* (118 Ma, Early Cretaceous) and slightly to the east, *Sylhet* (116 Ma), near the Assam/Bangladesh boundary. The source of these two traps is thought to be the Kerguelen hotspot (HI). In later time this may have also generated the Ninetyeast Ridge (or 90° E Ridge, cf. II.2.2.7). The *Emeishan* traps formed in China towards 260 Ma (Paleozoic, at the limit Middle Permian/Late Permian).

The huge *Siberia* traps mentioned above presently outcrop over the majority of the eastern part of the Siberian craton. Some remnants are found further to the north in the southern part of the Taymir peninsula (only visible in the Artic map in polar projection). Originally, these traps covered a much larger area (some authors give an estimate of about 4 million km², or even more). The **red dashed-dotted line** drawn on the West Siberian plain corresponds to a minimal estimate of their western extension beneath the Meso-Cenozoic sedimentary deposits (Reichow *et al.*, 2002).

Finally, a large **red dashed line** figures the boundary (that one can follow from the east of North America and the NE of South America to the west of Africa and Europe, drawn after J.G. McHone, 2003) of a sole large magmatic province. This boundary outlines the traps of the ***CAMP*** (*Central Atlantic Magmatic Province*) generated by a hotspot 200 million years ago (limit Triassic/Jurassic) shortly before the opening of the Central Atlantic dislocated this ensemble. Although the erosion caused the disappearance of piling-up of lava flows, the CAMP was reconstructed thanks to the occurence of related sills and dykes (volcanic intrusive bodies), that underlaid the surface outpourings.

A last point to explain concerning the continental LIP: the **Seychelles** Islands are made of Neoproterozoic (**P5**) granites marked by an arrow because these islands are hardly distinguishable on the Map. These granites are intruded by 65 Ma old dykes (figured also by an arrow and a **red asterisk**). This is the evidence that the Seychelles micro-continent was part of India during the times of the Deccan traps eruption.

II.1.4- Glaciers, inlandsis

Glaciers of some importance were mapped in the far south of the Andes, along with those covering islands of the far North Canada and Eurasia. They were assigned the same color as the Greenland and Antarctica ice caps (light grey). For the latter inlandsis, the zero meter level contour (sea level) was drawn. The areas oulined by these contours represent the subglacial bedrock lowered by the ice loading were distinguished from the ice caps using a darker hue (light purple).

II.1.5- Structural features

[5] This term and its abbreviation LIP are currently used in the international geoscience community and were coined in 1994 by Millard Coffin and Olav Eldholm. *Rev. Geophysics*, 32 :1-36.

[6] "K/T" for Cretaceous/Tertiary. The use of the term « Tertiary » that corresponded to the Cenozoic without the Quaternary, should be avoided.from now on.

[7] The large chronostratrigraphic delimitations (eras, periods, epochs) were created in the XIX century after the observation of sudden, very important and generalized changes, in the association of fossiles and micro-fossiles contained in the sedimentary deposits, mainly marine facies.

With the exception of Iceland (cf. II.1.6), the Afar (II.2.2.4) and the Makran (II.2.2.6), the onshore areas show only two structural features: the large normal faults and those of undertermined nature (black line); the large thrust fronts (jagged black line) curving round the large orogenic belts; Alpine (Alpes-Carpathian Mountains, Caucasus, Himalayas, Maghrebides, Rocky Mountains, Andes) or the older Hercynian (variscan, Urals, etc.), Caledonian (Appalachian, northern British Isles, western Scandinavia, ...) and even the roots of Precambrian belts (Canadian shield, etc.).

Among the many large structural lineaments on the map, it is worth noting the following:

- A line extending from the south of Norway to the Black Sea (Tornquist-Teisseyre line) that separates the "Precambrian Eo-Europe", including the Baltic shield (more appropriately called Fenno-Scandian shield), and the Archean and Proterozoic outcrops in Ukraine, from the pattern seen in more recent European structures (Paleo-, Meso-, Neo-Europe).
- The continental rift system emplaced since the Oligocene which stretches across Western Europe from the northern North Sea to the Gulf of Lion via the Rhine valley and the Rhodanian corridor. It is punctuated locally by volcanic complexes (i.e. Vogelsberg and Eifel in Rhineland-Hesse, Cantal and Chaîne des Puys in Auvergne).
- The large Amazon graben which isolates the two Guyanan shields from the Brasilian cratons (Central Amazonas and São-Francisco) to the south.
- A large and old SW-NE fracture cutting the Africa in two from the Gulf of Guinea across to the middle part of the Red Sea.
- The great East-African rift valley system, emplaced during the Cenozoic, and its relationship to the Afar hotspot (H1) and the opening of the Gulf of Aden and the Red Sea. The rifts are often occupied by great lakes. From north to south are: Turkana, Albert, Edward, Kivu, Tanganyika and Malawi lakes often punctuated by important volcanism. Should this continental rift and spreading persist, the East-African Rift will progressively become an oceanic lineament similar to the Red Sea and eventually be of the form of the Gulf of Aden and separate the "Somalia" plate from the rest of Africa, named "Nubia" plate by some geologists.
- The large faults that extend from the Pamir in a fan-like pattern between China and SE Asia. These wrench faults worked in response to the continuous push that the Indian sub-continent has been exerting against the east of the Eurasian continent for some 50 million years. Faults such as Altyn-Tagh (SW-NE) and Kunlun (W-E) carved out great basins such as Tarim (in the Xin Jian or Chinese Turkestan).
- Again in Africa, it is worthy noting the existence of the "Great Zimbabwe Dyke", a narrow strip of intrusive Paleoproterozoic, stretching N-S for 550 km, whose width does not exceed ten kilometers.

II.1.6- The Iceland case

The entirely volcanic island of Iceland covers a significant area (103 000 km²) and has an exclusively oceanic origin. It was built on a substratum of oceanic crust modified by a powerful hotspot (marked HD on Sheet 2) and is linked to the opening of the North Atlantic (north of 60°N). The axis of the Mid-Atlantic (spreading) Ridge runs across the island to separate two distinct geodynamic domains; the Eurasian plate to the east, and the North American plate to the west. Instead of mapping this island in the same way as the rest of the onshore areas (i.e. in "V1"), as in the former editions, it was decided to represent it as a surface of oceanic crust where Plio-Quaternary and Miocene basalts are distinguished from each side of the spreading axis.

II.2- OFFSHORE AREAS

The world ocean represents more than two thirds of our planet's surface (70,8%). It covers, on one hand, the submerged edges of the continents, the *continental margins*, and also the deep seafloor whose substratum consists of *oceanic crust* "produced" at the axes of the *spreading ridges,* also called "*Mid-Oceanic Ridges*". The average depth of the ocean is 3 700 m, a value much higher than the 800 m average elevation of the continents. The drawing of the offshore part of Sheet 2 was constructed, for some elements (spreading axes, transform faults/fracture zones, subduction zone axes, oceanic plateaus, hotspot tracks and other *anomalous* reliefs), by superposing the tracing draft of this sheet over the "Physiography" sheet.

II.2.1- CONTINENTAL MARGIN

II.2.1.1- Continent/Ocean Boundary (COB)

The boundary between the continental crust and the oceanic crust (**COB**) is shown by a **blue line**. This outlines the *passive continental margins* generated by the rifting of two separating continental blocks to form an ocean. Actually, this boundary is not that precise and one should include a transitional zone between a well identified continental crust and a "normal" oceanic crust characterized by well identified magnetic anomalies. The transition zone often displays a stretched and thinned continental crust intruded by peridotites that rise from the underlying mantle (exhumation).
Along the *active continental margins*, characterized by a *subduction zone*, the COB is well defined (corresponding to the subduction trench axis) and the above mentioned COB blue line is completely overwritten in this cartography by the specific line depicting the subduction (cf. II.2.2.6).

Considering the legal (and therefore political and economic) implications arising from the delimitation of the COB in the frame of the *United Nations Convention on the Law of the Sea (UNCLOS)*, it is expressly stated that the drawing of the COB limit on this Map is only approximative and sometimes conjectural, and that it does not have any legal status and neither is any implied.

II.2.1.2- Microcontinents

Some tiny « rafts » of continental crust (therefore encircled by a specific **blue line**) are shown on this Sheet isolated within an oceanic basin. They are named *microcontinents* and result from the complex history of the break-up and seafloor spreading in the formation of an ocean. This is the case in: (1) for the Seychelles platform in the Indian Ocean; (2) of the Jan Mayen microcontinent in the far North Atlantic; (3) of the Bollons seamount (60° S, 177° W) close to the New Zealand continental margin in the Pacific and (4) the South Orkneys microcontinent detached from the tip of the Antarctic Peninsula among others.

On the contrary, in this edition the Agulhas Bank (25°E, 40°S) to the south of South Africa, has no longer been assigned a continental nature. This is on the basis of recent works that suggest a volcanic origin of this quite large morphostructure built up on oceanic crust, as with the other large submarine reliefs of the SW Indian Ocean.

II.2.1.3- Island arcs

The island arcs follow the same mapping principle used for the continents and are bounded by the same medium blue line. It is known that they are the product of magmatic processes peculiar to the subduction events that lead to the formation of a “continentalized” crust (becoming thicker and lighter than the oceanic crust). It is probable that in a number of cases, such as in the Japanese archipelago, their substratum was detached from the nearby continent. This occurs through a general characteristic of the subduction mechanism known as “slab roll-back” that initiates at the beginning of the opening of a back-arc basin (or marginal basin; cf. II.2.2.4 et II.2.2.6).

II.2.1.4- Continental shelf

The continental shelves (or “continental platform”, or “continental terrace”) represent the innermost part of the continental margins. They extend from the coastline to the shelf break which tops the continental slope. The external limit of this shelf has an average depth of –132 m. For practical reasons, and given the scale of the Map, the commonly assigned –200 m isobath is used here to delineate the continental shelf since this depth is generally close to the shelf break. On this Sheet, and from a mapping point of view, the continental shelf was considered only from a morphologic point of view (a terrace) and conceals all other cartographic units it might overlay. Thus, the “continental” shelf of the Niger delta obliterates the oceanic nature of the underlying oceanic crust upon which the sedimentary fan of this large African river is prograding (i.e. it builds up seawards). The same applies to the “continental” shelf of Iceland, actually an island entirely generated by oceanic volcanism (cf. II.1.6).

All the continental (and island arc) shelf areas represents about 7.5% of the oceans surface. On the Map, the continental shelf is characterized by a light beige color. For practical reasons this cartographic unit also encompasses the shelves or terraces of atolls and volcanic islands that are not “genetically” continental but of oceanic origin (e.g. the Tuamotu archipelago). Indeed, the term “continental shelf” has a broader meaning in the formulation of the Law of the Sea (UNCLOS).

The continental platform is very narrow along many sectors of the African coast (only a few kilometers off Mogadishu, Somalia) and along the Brazilian margin south of the equator. On the island arcs, it is not well developed either. On the contrary, it is very wide off the coast of SE Asia (East China Sea, Sunda shelf), off Argentine Patagonia (up to 600 km wide) and a maximum extension can be observed along the Arctic front of Northern Eurasia (up to some 900 km on the continental shelf of Eastern Siberia).

The mapping of the continental shelf is one of the innovations of this third edition of the Map. It is an important element when considering the Quaternary palaeogeography of the world. It allows us to consider the withdrawal of sea level that occurred during the great Würm regression (ca. 20,000 years ago), the Last Glacial Maximum during which the sea level dropped by about 130 m. During this event, the volume of water removed from the oceans was transferred to build up the huge glacial ice caps in northern North America (up to 4 km thick above the Hudson Bay) and NW Eurasia. At that time, the English Channel and its Western Approaches were completely emerged. It was also possible to travel overland from the the far north of the Gulf of Siam to Bali, and from New Guinea to Australia.

II.2.1.5- Continental slope

The part of the continental margin located seaward of the shelf break and extending down to the contact with the oceanic crust (i.e. COB) is called continental slope. This term applies also to the island arc margins, as explained above. This element of the offshore morphology is represented in a yellowish green. The continental slope can be quite extensive, such as off southern South America where the spur bearing the Falkland Islands projects itself to the east towards the South Sandwich island arc over more than 1 500 km.

II.2.1.6- The Antarctic margin

The continental margin of Antarctica presents specific morphological characteristics owing to the isostatic loading excerted on the continental lithosphere for some 30 Ma by its huge ice cap. The most salient characteristics are: the frequent presence of a nearshore depression (down to 1 000 m deep) and a continental terrace abnormally lowered (from –400 to –700) in front of the shelf break. Therefore the continental shelf and continental slope have been merged into a single map unit shown in a light yellowish green to differentiate it from that of the continental slope.

II.2.1.7- Ice-shelf

For glaciologists, an ice-shelf is a thick volume of ice creeping ("flowing" slowly) from the ice cap to beyond the coast and has the form of a glacial sheet floating above a continental terrace. Its thickness varies from 100 to 1 000 m. These platforms are characterized on the Map by a blueish grey color. The ice-shelves of Greenland and Canadian Arctic Islands, too small at the scale of the Map, were not plotted. The Antarctic ice-shelves have a total surface of about 1.5 million km² and could be highly affected by the ongoing climate change. The largest ice-shelves are the Ronne to the "north", and the Ross to the "south", the latter partially encircling Ross Island, location of the active volcano Erebus (cf. Sheet 1).

Ice-shelves should not be mistaken for pack ice, the latter being a thin ice sheet (few meters thickness) of frozen seawater. Their size significantly changes during the seasons of the year.

II.2.2- OCEANIC BASINS

Oceanic basins are that part of the seafloor whose basaltic substratum is made up of oceanic crust. They are overlain by sediments, except in the axial zones of the mid-oceanic ridges. Their history and structure differ drastically from that of the continents. Oceanic basins cover about 59% of the planet surface. Five main types of morphostructures are to be distinguished: • abyssal plains; • mid-oceanic ridges; • large fracture zones; • subduction trenches; • "anomalous" oceanic features, i.e. structure of volcanic origin whose genesis postdates the age of the oceanic crust on which they have been built up.

II.2.2.1- Age of the oceanic crust

In comparison with the age of the continents, whose oldest outcropping nuclei have been dated at some 4 Ga (billion years), the age of the oceanic basins substratum never exceeds 200 Ma (million years). In the present state of knowledge the oldest ages are Middle Jurassic (starting at 175.6 Ma). These are found off the eastern margin of the United States and off its conjugated margin of Western Africa (both margins fitted into each other before the opening of the Central Atlantic). They also exist in the Central part of Western Pacific. As Earth volume is constant [8], every piece of oceanic crust formed at the axes of mid-oceanic ridges prior to this limit of 200 Ma was necessarily entirely "swallowed" by the subduction process, trapped as slivers within continental collision or overthrust during an obduction (cf. II.1.2).

The mapping of the age of the oceanic crust was made by interpolation of the position of the magnetic anomalies generated by the effect of periodic inversion of the Earth magnetic field on newly formed crust (cf. Müller et al., 1997). In this map we have displayed only the limits of the chronostratigraphic units shown: Plio-Quaternary – Miocene – Oligocene – Eocene – Paleocene – Upper Cretaceous – Lower Cretaceous – Upper Jurassic – Middle Jurassic (cf. the relevant legend). The colours for the different oceanic units are those currently used for CGMW seafloor maps.

For the enclosed basins such as the Arctic basins, the remnants of the ancient Tethys Ocean (Eastern Mediterranean) and back-arcs basins, where the age of the crust is sometimes not precisely known, a larger age range was used (e.g. Undifferentiated Jurassic- Cretaceous for the Eastern Mediterranean, or Neogene for the marginal basin located to the south of the Banda Sea, Indonesia). Moreover in some sectors, where the colors might not be clearly discernible, the age is also given by the corresponding symbol in the legend (e.g. "j3" for the South Caspian basin, or "g" for the Celebes basin).

Finally, shown in grey are a number of oceanic areas where the magnetic anomalies have so far not been identified by geophysicists and where the age of the crust remains undetermined. They are to be found mainly around Antarctica, and to the east and SE of Australia.

II.2.2.2- Abyssal plains

The abyssal plains are characterized by a very flat sea bed with a, sometimes quite thick, sedimentary cover that exends to both sides of the mid-oceanic ridges. Their depth (blue hues on the physiography of Sheet 1) increases imperceptibly from some 4000 m to a little over 6 000 m. Schematically, the age, the density and the depth of the basaltic substratum increase with the distance from the axis of the mid-oceanic ridge. Likewise, the thickness of the sedimentary cover increases with the distance from the mid-oceanic ridge[9]. A good example of a well individualized abyssal plain, free of anomalous reliefs, is the Argentine basin – whose centre deepens to more than 6 000 m depth – surrounded by the South Atlantic mid-oceanic ridge, the Falkland spur and the Argentine continental margin.

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[8] From the end of Fifties onward, the Australian geologist Samuel Warren Carey proposed the theory of the *expanding Earth* where the surface of our planet must have been increasing for the last 200 Ma which is correlative to the break-up of the supercontinent Pangea and to the continental drift. Consequently, he dismissed the existence of subduction zones. This theory was (almost) definitively abandonned.

[9] Their thickness can reach several thousand meters when approaching the foot of certain continental margins, in particular those where the terrigenous supply comes from the high sedimentary input of very large river systems (Amazon, Ganges/Brahmaputra, Indus, ...).

II.2.2.3- Mid-oceanic ridges

The mid-oceanic ridges (or oceanic accretionary ridges) form the largest mountain range in the world with a total length of nearly 80 000 km[10] that extends through the four oceans. Starting at the base of the continental margin of the Lena river delta (Eastern Siberia) in the Arctic, this system runs through the Atlantic from north to south, enters the Indian Ocean (with a northern branch running up to the Red Sea[11], generates a "triple junction" of ridges to the SE of Reunion island), then rounds the southern tip of New Zealand continental margin to step into the Pacific. In this latter ocean, the oceanic ridge is not in a mid-oceanic position but is largely offset to the east (justifying thereby its East-Pacific Ridge/Rise or EPR label) before "dying" in the Gulf of California (or Cortes Sea). From this long ridge, originate two branches extending to South America: the South Chile Ridge and the Galapagos Ridge. Farther to the north, the Juan de Fuca Ridge is located at some distance from the coast extending from the north of California to British Columbia. This small oceanic ridge is linked to the Gulf of California along the San Andreas transform fault system (cf. II.2.2.5). The Juan de Fuca and the EPR formed a single continuous ridge before the now missing segment was “swallowed” beneath present-day California by the former subduction zone.

With a width varying from 1 000 to 3 000 km, the oceanic ridges rise 2 500 to 3 000 m above the abyssal plains. The mean depth of the crest of these ridges is about 2 500 m beneath the sea level. They occupy nearly a third of the surface of the seafloor.

The Mid-Atlantic Ridge, with its winding outline similar to that of the two sets of conjugated continental margins, is the type example of seafloor spreading and related continental fit.

II. 2.2.4- Axis of mid-oceanic ridges

The axis of active mid-oceanic ridges marks the boundary between two divergent lithospheric plates. This boundary is characterized by seismic activity. The axes are represented by a continuous red line, a color that recalls the fact that they are a key element of the Earth volcanism since they are, geologically speaking, continuously providing magma. Depending on whether the divergence rate is low or high[12], the morphology of the ridge differs. At low spreading rates (2 to 3 cm/year), as in the Atlantic, the topography is rough and shows a deep axial valley (rift). At high spreading velocities (about 15 cm/year), as in the East-Pacific Rise, the topography is smoother without deep axial valleys. This contrast is strikingly noticeable on Sheet 1 (Physiography).

The particular case of Iceland, with its subaerial oceanic accretionary rifts, was mentioned above (II.1.6). As for the Afar "triangle" (also located above a hotspot, marked HA), this represents a "triple junction" where the Gulf of Aden (a continuation of the active Carlsberg ridge in the northern half of Indian Ocean), the Red Sea oceanic rift and the Great East African Rift converge. Although the Afar is still largely of continental nature, three small segments of oceanic accretionary axes are plotted somewhat schematically to figure the (possible) beginnings of a future oceanization (if the present geodynamic context remains unmodified, cf. II.1.5).

Concerning the back-arc basins (or "marginal basins) that open "behind" an island arc (i.e. on the opposite side to the subduction trench), a micro-ocean forms and therefore the oceanic accretionary axis is represented by the same red line as for the oceans. This can be seen in the marginal basin of the Mariana island arc (Western Pacific), the Lau Basin that opens behind the Tonga island arc (SW Pacific) and the South Sandwich back-arc basin (formerly named Southern Lesser Antilles), a part of the loop linking southernmost Andes to the Antarctic Peninsula. An incipient stage of back-arc spreading is occurring in the Okinawa Basin to the west of the Ryukyu island arc (southernmost Japan archipelago), with a series of small active en echelon segments that begin to cut out the continental margin of the East China Sea. A more advanced stage is found in the (very narrow) Bransfield marginal basin located at the rear of the South Shetland subduction zone within the Antarctic Peninsula.

The extinct axes of oceanic accretion are figured like the active axes (by way of a red dashed line), as e.g. in the Scotia Sea (between South America and Antarctica), or in the Tasman Sea east of Australia. These are zones where the divergence stopped inside an ocean or a back-arc basin. One of the most interesting examples is that in an area of the North Atlantic where the spreading process began between Canada and Greenland in the Paleocene, then hesitated between west and east of Greenland in the Eocene. Eventually, this divergence ceased in the Labrador Sea and the Baffin Basin, and the opening jumped east to separate Greenland from northwestern Europe. The Labrador Sea is an aborted ocean with Greenland, after a stage of dissociation from the North American plate, reintegrated with the latter.

II.2.2.5- Transform faults,and fracture zones

One of the salient characteristics of the morphology of the oceanic basins is their sectioning, or slicing, by a set of long faults (black lines on the Map) that cut perpendicular to the mid-oceanic ridges. Between the ends of two successive segments of active axes, the fault undergoes strike-slip motion and is seismically active. This part is called a transform fault. Beyond and along the fault, there is no longer any lateral displacement between the two sides of the fault and it becomes a seismically inactive fracture zone (F.Z.) representing the "scar" of the transform fault. This type of complex

[10] The length goes down to some 60 000 km when taking into account only the cumulated length of the segments of oceanic accretionary axes.

[11] This branch heads first northwards with the Central Indian Ridge, then turns off north-westward with the Carlsberg Ridge, then runs westwards with the Gulf of Aden oceanic Ridge before connecting in a complex way, via the Afar zone, to the Red Sea.

[12] The figures correspond to average values over a certain time lapse; they don’t necessarily mean the spreading occurs regularly every year.

fault[13] frequently reaches a length of several thousand kilometers[14]. As one might expect, the largest fracture zones (some 6 000 km) are located in the Pacific Ocean: the Mendocino F.Z. (touching the eponymous cape, near the border between California and Oregon), the Clipperton F.Z., the Eltanin F.Z. system (between the Antarctica Peninsula and the continental margin of New Zealand) among others. Fracture zones are the markers of the rotation between two divergent plates controlled by plate tectonic geometries. The most remarkable example is provided by the Agulhas-Falkland F.Z. joining the tip of Southern Africa to the southern extremity of South. This F.Z. traces a near perfect small circle arc that aids reconstruction of the fanlike opening of the South Atlantic.

A good example of an important transform fault is the Owen FZ, in the NW Indian Ocean. This offsets the active ridge of the Gulf of Aden relative to that of Carlsberg Ridge[15] (located in the middle of the northern area of this ocean), and then links this accretionary system to the Makran subduction zone along the Pakistani and Iranian Baluchistans. This fault "transforms" therefore a divergent movement into a convergent one (cf. also II.2.3.6). This SW-NE fracture ends up in front of Karachi, directly facing the thrust front of the orogenic belts bordering the west of the Indus valley and connecting to the Himalayan collision belts. The Owen transform fault with its dextral motion[16], constitutes the boundary between the Indo-Australian and the Arabian plates.

On Sheet 2, only 22 examples of movements of large transform faults (or simply large wrench faults) are plotted (double half black arrows in opposite directions) either in an oceanic or continental domains. Only 3 examples are mentioned here: 1- the transform faults that constitute the northern (left-lateral) and southern (right-lateral) boundaries of the Caribbean Plate; 2- the right-lateral transform fault of San Andreas (sensu lato) linking the opening system of the Gulf of California, cutting through all the west of California and ending up at Mendocino Cape where it connects to the axis of the Juan de Fuca oceanic ridge; and 3- the left-lateral Levant fault joining the Red Sea to the collision zone of the Arabian plate with Anatolia, and where its locally step-like shape opens the small Dead Sea and Sea of Galilee basins[17].

II.2.2.6- Subduction zones, subduction trenches and other trenches

Like all plate boundaries subduction zones are seismically active[18]. However, in the tectonics of convergence, the (heavier) oceanic lithosphere of a subducting plate dips as a more or less slanting slab beneath the edge of the overlying plate whose lithosphere is made of either the lighter continental crust (case of a arc-cordillera) or continentalized crust (case of an island arc behind which one finds a back-arc basin, or marginal basin, of oceanic origin). This is the reason why subduction zones are also denominated as active margins, in contrast to non-seismically active passive margins which result from the drifting of two continental blocks from either side of an initial rift (as in the case of the Atlantic). The subduction of oceanic crust generally produces a volcanic line that is at the origin of island or cordillera arcs (cf. also II.2.1.3). These volcanoes (characterized by explosive, hence dangerous, eruptions) are located above a strip of the subduction slab, starting at a depth of some 100 km, where it begins to become dehydrated[19]. A case is the Pacific 'Ring of Fire'.

The total length of the subduction zones is approximatively 55 000 km, a size comparable to that of the mid-oceanic ridges (cf. note 10).

The active subduction zones are shown by a green line with solid triangles whose tops are situated on the leading (overlying) plate to indicate the direction of the subduction. The convexity of island arcs is always facing the subduction trench (e.g. Lesser Antilles in the Atlantic, Mariana in the Western Pacific), but a rectilinear shape may occur (e.g. the Tonga-Kermadec in the SW Pacific). On the concave side of the island arcs, a back-arc basin opens by separating itself either from a continent (as in the case of Japan where a small oceanic basin within the Japan Sea partially separates it from the eastern continental margin of Asia), or from another island arc that has become a remnant arc, i.e. extinct. The latter is illustrated in the case of the Mariana active arc→West Mariana (opening marginal) basin→West Mariana (remnant) ridge, or the activeTonga arc→opening Lau Basin→remnant Lau Ridge.

The convergence zones are generally characterized in the submarine morphology by a subduction trench, a long and narrow depression normally delineated by the 5 000 or 6 000 m isobath. The greatest depth recorded is 10 920 m in the southern part of the Mariana Trench (Sheet 1). Trenches are not always visible because, in some areas, voluminous sedimentary input are released into the ocean by large river systems that fill up part of the trench lengthwise. The upper part of the sedimentary cover of the dipping plate abuts againtst the backstop (i.e. the rim of the leading plate) instead of being swallowed by the subduction, and is hence "scraped off" (thus escaping absorption into the Earth's mantle). This becomes piled up as imbricate thrust slices in front of the arc. Hence an accretionary sedimentary prism forms, the deformation front of which is indicated on the Map by a symbol similar to that of the subduction, but colored light blue

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[13] For English-speaking authors, the terms of *transform fault* and *fracture zone* seem somewhat synonymous.

[14] In spherical geometry, any mouvement corresponds to a rotation movement whose axis passes through the center of the Earth. The fracture zones consequently follow small circles centered on the plates' rotation poles (which are to be distinguished from the planet's rotation axis poles).

[15] See note 11.

[16] The strike-slip movement is defined by standing on either side of the fault and observing the direction of the motion of the opposite side. If it moves to the right, the movement is *dextral* or *right-lateral;* if it moves to the left, it is *sinistral* or *left lateral*.

[17] These small basins generated by strike-slip faults are more commonly called "*pull-apart basins*".

[18] A part of the earthquakes generated by the subduction are distributed along the dipping lithosphere; This seismic slab is called "Wadati- Benioff zone", after the name of the two geophysicists who discovered this phenomenon.

[19] The part of the dipping "slab" generating the subduction volcanoes is located at a depth rarely exceeding 150 km.

with open triangles. In the region between this thrust front and the axis of the filled part of the subduction trench it was decided to show the age of the underlying oceanic crust, as yet to be subducted but, concealed by the sedimentary prism that would have otherwise been shown as part of the arc margin. The most remarkable illustration is provided by the Barbados accretionary prism, located in front of the southern half of the Lesser Antilles arc. As a consequence of a huge sedimentary input coming from the Amazon and Orinoco rivers, the maximum thickness of this accretionary sedimentary prism reaches some 20 km beneath the island of Barbados. Two other prisms are drawn on the Map: the Mediterranean complex located to the south of Calabria and Greece, and the Makran. An interesting feature of the latter is that the inner part of the prism has emerged and constitutes the coastal region of Baluchistan. This is the reason why, in this case, the axis of the subduction is plotted onshore and indicates the contact between, on one side, the "backstop" represented by the lithosphere of the leading plate (Eurasia), and on the other side the lithosphere of the subducting plate (Arabia).

There are very few places where an incipient subduction presently occurs. It represented on the Map by the symbol of active subduction (but with green open triangles). This is the case of the Musseau Trench (about 149° E, 05° N) where the Caroline plate begins to dip beneath the large Pacific plate. This also occurs the north of the Lesser Sunda island arc (subducting southwards) in order to accommodate the docking of the Australian continental margin as a result of its northward convergence toward the Sunda arc.

It is worth noting a case of extinct subduction (represented by a similar symbol, but in purple dashed/dotted line) in the Vitiaz Trench whose maximum depth is only 5 600 m and stretches from the Solomon Archipelago to the northern tip of the Tonga arc. During the Miocene, the arrival of the Ontong Java oceanic plateau blocked the whole system (cf. II.2.2.7) because it was not dense enough (buoyancy effect) to be absorbed by the subduction of the Pacific Plate which was previously subducting southwards under the Indian-Australian plate. This caused reorganization of the subduction as it now dips in an opposite direction under the New Hebrides arc.

The subduction zones are mainly concentrated around the Pacific rim and are the modern expression of the old fashioned term "Pacific ring of fire". In this ocean, there is a striking contrast between the island arcs (active or remnant) and their marginal basins which are exclusively distributed to the west, while to the east the subduction zones are only dominated by volcanic cordilleras (Andes, volcanic ranges of Central America, Rocky Mountains). Outside the Pacific only two subduction systems exist in the Indian Ocean, those in front of the Sunda Islands and that of the Makran, and two in the Atlantic, with the subduction of the Lesser Antilles and in the Scotia arc (between South America and Antarctica).

Not all submarine trenches are exclusively related to subduction. Some exist along transform faults that cut across the axis of mid-oceanic ridges, particularly when the spreading rate is low. The Romanche Trench, in Central Atlantic (centered on the equator by 18° W, 300 km long) has the record for this type of feature with 7 758 m depth.

II.2.2.7- "Anomalous" submarine features (seamounts, oceanic plateaus, hotspots tracks)

These constitute on Sheet 2 a large ensemble of all sized reliefs that affects the oceans and is represented by the same orange-brown hue recalling, in a subdued way, the colour of the traps on continents[20]. Actually, all these features result from a generally powerful magmatic activity postdating the age of the "normal" oceanic crust[21]. This magmatism affects the oceanic crust initially produced at the axis of the mid-oceanic ridges. If the structure of the oceanic basins were controlled only by the plate tectonics principles, the ocean would only display mid-oceanic ridges, fracture zones, abyssal plains, and subduction trenches with their associated island arcs. All these features, thus being of volcanic origin, are generated by the activity of a hotspot (whatever the signification attached to this concept, cf. II.3) having, with some exceptions, a relatively stationary position. They are of three types:

- *submarine seamounts*, relatively small, mainly covered by sediments, and whose summit is sometimes flat (in this case called "guyots"), resulting from the erosion of a subaerial volcano sinking progressively beneath the sea under the effect of normal thermal subsidence.
- *oceanic plateaus* (cf. also II.1.3).
- *hotspots tracks (or trails)*, formerly denominated "*aseismic ridges*" because these ridges lack of seismic activity compared to the mid-oceanic ridges located at plate boundaries.

Geologically speaking an **oceanic plateau** is generally built up during a short period of time from a pulse of intense hotspot activity. A number in **red** followed by **Ma** indicates **the average age** of the plateau (e.g. "123 Ma" for the age of the Manihiki plateau, to the NE of Samoa), or as two numbers separated by **&** when the build-up is believed to have occurred in 2 main pulses. When the age is uncertain inside a time lapse, the range is given by two hyphenated numbers. The age, sometimes quite approximate, is given only for 10 oceanic plateaus: in the Indian Ocean, the *Maud Rise* (73 Ma ; 0°E/W, 65,5° S), the *Kerguelen Plateau* (119 Ma & 100 Ma), *Broken Ridge Plateau* (95 Ma ; 95°E, 30°S) ; in the Pacific Ocean: the *Shatsky Rise* (147 Ma ; 160°E, 35°N), the *Hess Rise* (99 Ma ; 180° E/W, 35°N), the *Manihiki Plateau* (123 Ma ; 165°W, 10°S), the *Ontong Java Plateau* (121 Ma & 90 Ma), the *Hikurangi Plateau* (120-100 Ma, close to the east of New Zealand) ; in the Atlantic Ocean, the *Caribbean Plateau* (90 Ma & 76 Ma), and the *Sierra Leone Rise* (73 Ma ; 20°W, 05°N).

The Ontong-Java oceanic plateau, named after the atoll located north of the Solomon Archipelago, is by far the most remarkable. It has the largest surface area, estimated at some 2 million km², and a volume of some 40-45 million km3

[20] **Violet contours** drawn inside these structures correspond to **second order reliefs.**

[21] See the reservations to be considered in relation to this statement in II.3.

with an anomalous crust whose thickness can reach more than 30 km. It was formed in the middle of the Cretaceous Period, ca. 122 Ma, and probably also during a second magmatic pulse around 90 Ma. Some authors believe that this plateau was generated by the "plume" of the Louisville hotspot (marked HE on this Sheet) situated in the south of the Pacific (140° W, 50°S)[22]. As mentioned above (II.2.2.6), this plateau reached the former Vitiaz subduction zone some 20 Ma ago, then collided with the Solomon island arc about 4 Ma ago. This caused the blocking of the subduction because of its lower density compared to the normal oceanic crust (buoyancy effect).

According to the classical theory, a hotspot is located more or less deep beneath a lithospheric plate that is moving over it with a velocity and direction controlled by the accretionary axis where that plate is being generated. In its early existence, the hotspot generates a large plume. When reaching the overlying lithosphere, it produces a voluminous and relatively fluid volcanism at the surface in quite a short time lapse in geological terms. Subsequently, large outpourings are formed in contained, but somehow large, geographic areas: traps, onshore, and oceanic plateaus, offshore[23]. After dissipation of the plume, only the "tail" of the hotspot remains active, evidently at a lower rate but for a much more extended period of time. This activity is recorded in the moving overlying plate by a chain of volcanoes that drift away from the feeding hotspot, first as an active volcanic center, then extinct, and finally subsiding below the ocean surface. The links in this volcanic chain become progressively older with the distance from the hotspot.

The whole set of this linear chain forms the hotspot track (or hotspot trail). The most illustrative example is given by the Hawaii hotspot (code HC on Sheet 2) where the volcanic activity is at present located beneath The Big Island (Mauna Loa and Kilauea shield-volcanoes, and the submarine Loihi volcano[24] marked by a small blue triangle on Sheet 1). The oldest part of this hotspot track still visible is the Meiji seamount (dated at 85 Ma), located just in front of the Kuriles subduction zone which will eventually subduct it. Notice that at halfway along its length (ca. 40 Ma), the orientation of the hotspot track changes from SE-NW to S-N direction, evidence of the reorientation of the motion of the Pacific Plate at that time.

In addition to the above mentioned Hawaii hotspot track, the age of some different progression steps for 5 other trails is indicated in the map with a red number without the "Ma":

- *La Réunion* (HF). A trail that links this island to the *Deccan* traps via Mauritius Island, Nazareth Bank, Chagos Bank, Maldives and Laccadives ridge. The subsequent opening of the Arabian Sea from the creation of the Carlsberg mid-oceanic ridge has cut this trail in two and offset the original alignment that also included the Saya de Malha and Seychelles banks (cf. also II.I.3).
- *Kerguelen* hotspot (Hi) probably at the origin of the Broken Ridge Plateau and the Ninetyeast Ridge[25] and perhaps of the *Rajmahal* and *Sylhet* remnant traps.
- *Louisville* hotspot (HE) whose trail (Louisville Ridge) ends up at the Tonga-Kermadec subduction zone (and maybe at the origin of the Ontong Java Plateau, as seen above[26]).
- *Tristan da Cunha* hotspot (HG), at the origin of the Rio Grande Rise to the west, and of the Walvis Ridge to the east, that are connected to the Parana and Etendeka traps respectively that, as seen before (cf. II.1.3), formed a single LIP unit 133 Ma years ago, before the opening of the South Atlantic.
- *Easter Island* hotspot (HB) that produced the Sala y Gomez Ridge continued by the Nazca Ridge whose eastern extremity is subducted into the Peru Trench.

II.2.2.8- Distributed or diffuse plate boundaries

A grey hatching covers some oceanic areas where the transform boundary (strike-slip motion) between two lithospheric plates is ill-defined. It is distributed over an area of variable width, e.g. between the North America and South America plates, or on a part of the transform fault to the east of Azores separating Eurasia from the African plate.

The largest region displaying this kind of diffuse boundary is located in the middle of the Indian Ocean where it links a segment of the Central Indian (accretionary) mid-oceanic ridge to the Sunda subduction zone (from the north of Sumatra to the middle of Java). This crosses the whole width of the so-called Indian-Australian plate. Actually, it is not yet a true boundary showing a clear separation between an Indian plate and an Australian plate, but a zone where the basaltic substratum is deformed by a compressive stress (in response to the collision of India against Tibet) and where diffuse seismicity also occurs.

22 The formation of the Ontong Java plateau by a hotspot was recently questioned by the hypothesis of a very large meteoritic impact triggering a cataclysmic magmatic output (cf. Ingle S. & Coffin M., 2004, *E.P.S.L.*, 218 :123-134).

23 At present, there are not known examples of trap or oceanic plateau in formation.

24 The Loihi, located 34 km to the SE of Big Island and culminating at a depth of –1000 m (at the "Pelé Pit"), is the most recent expression of the Hawaii hotspot.

25 The name of the ridge was coined after its specific geographic position located along meridian 90° E.

26 In this case, the missing segment would have been progressively absorbed by this subduction, since the motion of the Pacific Plate was westwards.

II.2.2.9- Submarine volcanism related to the opening of the North Atlantic Ocean

A red hatching overprint shows the presence of SDRs (Seaward Dipping Reflector sequences), located from seismic reflection surveys, or submarine basalt bodies. The latter can be both outcropping or buried and all provide evidence of an extensive volcanic province related to the opening of the North Atlantic Ocean during the Paleogene (cf.II.2.2.4), and to the activity of the powerful Iceland (HD) hotspot. These dynamics had an effect on the conjugate continental margins of Greenland (and sometimes beyond), on one hand, and of the British Isles and Norway, on the other. This eruptive activity is known onshore (volcanism "V 1" in the legend) in Greenland, as well as in the Faroe Islands and Ireland (Giant's Causeway). It is interpreted that the SDRs correspond to a series of strata with alternated volcanic flows (lava and pyroclastic deposits) and non-volcanic sedimentary layers.

II.2.2.10- SDRs related to the opening of the South Atlantic Ocean

In the South Atlantic Ocean, oil exploration has more recently located SDRs (blue hatching) on the conjugated continental margins of Argentina and Namibia-South Africa. The presence of these reflectors is related to the opening of the South Atlantic Ocean and the presence of the Tristan da Cunha (HG) hotspot.

The two examples of these Atlantic basins show that the passive continental margins (i.e. generated by an earlier continental rift and no longer constituting a plate boundary) are not solely "non volcanic", as previously presumed before the discovery of SDRs. It might give some evidence for the presence of a hotspot being required in the initial rifting of a continental block and the subsequent opening of an ocean.

II.3 – HOTSPOTS

The hotspot theory (cf. II.1.3; II.2.2.7) was proposed by the Canadian geophysicist John Tuzo Wilson who first proposed it in 1963 (two years before he developed the transform fault theory) taking Hawaii as a base model. This attractive theory had enormous success in consistently explaining the distribution of specific volcanism generally seen outside the plate boundaries (hence its name of intraplate volcanism) and is particularly evident in the oceanic domain. The initial hotspot list included a score of cases, but its number rapidly expanded to 130 units, even more indeed (about 5 200 according to Malamud and Turcotte in 1999). However at this point, quoting Don Anderson and Kimberly Schramm27, "this brings up the question of semantics" (see footnote 28). Today, the list has been brought down to a more reasonable number varying between 40 and 50 hotspots. But not all of them meet the basic criteria of the original model (without addressing the geochemical domain). These are: a deep origin for the mantle plume and a long duration of the activity (several tens of million years) which determines the progression of a volcanic track in surface. Those cases, disagreeing with the classic model, are labelled shallow, weak hotspots or hotlines, etc. The latter is exemplified by the NE-SW Cameroon volcanic line where the age of the volcanism is not distributed according to a regular migration throughout time. It shows a more or less random mode, with the currently most active volcano being the coastal Mount Cameroon (+4 095 m) half-way between the extremities of the line located one at the north of the Cameroon Republic, and the other beyond the small Pagalu Island (ex-Annobon). The polemics around the hotspot concept has been hardening since the early 2000s, when some researchers (anti-plumers, see e.g. the recent works of Don L. Anderson) denied the existence of a number of plumes. They proposed an explanation for the origin of LIP (Large Igneous Provinces, cf. II.1.3) mainly attributed to dynamics related only to the plate tectonics sensu stricto, which induce shear stress in the lithosphere favoured by pre-existing lines of weakness such as fracture zones28. This case seems to apply to the Central Pacific –see in particular the works of IRD/IPGP (Valérie Clouard and Alain Bonneville) and USGS (Marcia McNutt and collaborators)– with the hotspot track segments of Samoa (H27)-Rarotonga (H25)-Arago (H1)-Mcdonald (H21)-Foundation (H15), and with the Tahiti (H30)-Pitcairn (H24) segment.

This current controversy is hosted by the very interesting web site: < www.mantleplumes.org >.

Whatever it might be, it was considered of informative interest to plot the exact or inferred position of 45 hotspots on the Sheet 2 (list given in the inset placed in the bottom of the Map).

They are categorized in 4 types of hotspots, taking into consideration the criteria of Vincent Courtillot and co-workers (2003) in particular:

1/ "primary" hotspots interpreted to correspond to a powerful plume, deeply rooted in the lower mantle and with a long duration, marked HA to HG (large red continuous circle);

2/ hotspots that might be considered as primary, shown Hh to Hi (large red dotted circle);

3/ less characteristic, problematic or controversial hotspots, noted H1 to H34 (small red circle);

4/ hotspots supposed to has been extinct since much over 1 Ma, but which would have left traces in the seafloor morphology (small blue circle). This would include the Great Meteor Bank (eH1) to the south of Azores that would have built the New England seamount alignment and Saint Helena (eH2).

The first three categories, considered as "alive" with an active, or recent (as in Hoggar) volcanism are mainly located at one extremity of the trail. Most hotspots are to be found in the oceans. Only 6 are onshore: Afar (HA), Cameroon (H17), Darfur/Djebel Marra (H13), Hoggar (H17), Tibesti (H32), Yellowstone (H34).

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27 Cf. D. Anderson and J. Natland, (p.134), see complete reference in foot note 28.

28 D. Anderson & K. Schramm use in their paper « The complete hotspot catalogue » *in* :*Plates Plumes & Paradigms* (Geol. Soc. Amer., Special Paper no. 558, 2005, p. 19-29), with some humour, the neologisms « Notspots » and « Crackspots » to refer to these "dethroned" hotspots.

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By way of conclusion….

… It is to be noted that Sheet 2 can be used as a basis to explicitly trace the contours of the different lithospheric plates, sub-plates, and micro-plates that make up the present surface of our planet through a relentless confrontation between creation dynamics and destructive processes. Two maps formerly published at the same 1:50,000,000 scale by CGMW usefully supplement the reading of this Map:

Plate tectonics from space (2006, N. Chamot-Rooke & A. Rabaute) displaying the present-day motions of the lithospheric plates, one in respect to the others;

Seismotectonic Map of the World (2002, A. Haghipour and coll.) showing the distribution of the earthquakes, particularly along plate boundaries, with different categories of magnitudes and focal depths of earthquakes.

Translation into English by Philippe Bouysse & Clara Cárdenas (CGMW), reviewed by Peter Miles (CGMW) and Françoise Cadet (University Paris VI).

Avertissement

On ne s'étonnera pas de trouver au texte de ces notes un caractère quelque peu hétérogène, mêlant une information classique destinée aux professionnels des géosciences, utilisateurs de référence des cartes géologiques, à des explications d'un niveau plus accessible. La raison en est que, outre un public non spécialisé, une partie significative du lectorat francophone des éditions antérieures de la Carte du Monde de la CCGM est constituée de lycéens, voire de collégiens.
Par ailleurs, il était impossible de commenter, dans ces Notes, tous les aspects géologiques, structuraux, ou géodynamiques que peut soulever un examen attentif de la Carte. Le déroulement du texte étant calqué sur le commentaire des légendes, nous nous sommes contenté de donner quelques coups de projecteur sur une sélection d'exemples qui, pensons-nous, illustrent de manière adéquate chacun des éléments de la légende.
On remarquera aussi qu'une certaine importance a été accordée, dans cette nouvelle édition, aux fonds océaniques, aux grands événements magmatiques, et à la géodynamique.

GÉNÉRALITÉS

Cette troisième édition de la *Carte géologique du Monde à 1/50 000 000* (1/50 M) fait suite aux première et deuxième éditions publiées par la CCGM, respectivement en 1990 et 2000. Ce document bilingue (français-anglais) est une compilation, très synthétique étant donné la petite échelle de la Carte, dont l'objectif est essentiellement pédagogique. C'est une tentative de représentation (très) simplifiée de la géologie de notre planète dans sa globalité : continents et fonds océaniques, côte à côte.

Cette nouvelle édition, **de conception entièrement rénovée** par rapport à la carte publiée en 2000, prend en compte l'état des connaissances géologiques à la charnière des XX^{è} et XXI^{è} siècles. Elle se présente, pour la première fois, en 2 feuilles, de même format :

- une **Feuille 1 (Physiographie, Volcans, Astroblèmes)** faisant ressortir le «grain» du modelé de la surface solide du globe terrestre, une fois les bassins océaniques vidés de leur contenu aqueux.
- une **Feuille 2 (Géologie, Structure)** donnant à voir les grands traits des différentes unités lithostratigraphiques et des principaux éléments structuraux qui dessinent la marqueterie actuelle de la surface de notre Terre, aboutissement de 4,56 milliards d'années[29] de mues incessantes. Cette deuxième feuille est l'équivalent, très notablement remanié et augmenté, de la feuille unique de la deuxième édition.

Chaque feuille comprend une carte principale en **projection Mercator**, et une représentation spécifique (projection stéréographique polaire) pour chacune des deux aires circumpolaires. Les maquettes ayant servi à la préparation de la carte principale ont été réalisées, avant leur numérisation en mode vectoriel, à l'échelle de 1/25 000 000 (1/25 M). Comme chacun sait, l'indication d'échelle en Mercator n'est strictement valable que le long de l'équateur. La carte principale permet une visualisation optimale de l'ensemble continents-océans, car elle ne privilégie pas la représentation des uns par rapport aux autres, comme nombre d'autres systèmes de projection. Mais son handicap provient du fait que les déformations croissent au fur et à mesure que l'on se dirige vers les hautes latitudes, pour devenir infinies aux pôles. Dans cette édition, les limites «haut» et «bas» ont été fixées à 72°N et 72°S pour la Feuille 2 (contre 78°N et 65°S pour les deux éditions précédentes), et 72°N et 70°S pour la Feuille 1. Il s'ensuit que, maintenant, une bonne partie de la marge et de la côte du continent Antarctique apparaît sur la projection Mercator, délimitant mieux l'océan Austral. Quant au Groenland, il reste toujours coupé en deux. L'extrême nord du continent eurasiatique est par contre amputé de la péninsule de Taymir.

Les **projections polaires** s'étendent jusqu'aux parallèles 60°N et 60°S (contre 70°N et 60°S pour les éditions précédentes), le Groenland y est désormais représenté dans sa totalité, et ces projections couvrent les mêmes aires circumpolaires. Pour en améliorer la lisibilité, l'échelle a été légèrement agrandie à 1/46 M.

Pour des raisons pratiques et de priorité de diffusion, cette 3ème édition est d'abord publiée à **l'échelle de 1/50 M** (pour la projection Mercator), avant de procéder ultérieurement à l'édition de la version originale (1/25 M) et d'une version numérique interactive (cédérom).
Dans les éditions antérieures à 1/25 M, la projection Mercator était imprimée en 2 coupures (20°W**-** 170°W; 170°W**-**20°W) ce qui permettait à chacun de réaliser l'assemblage de son choix : centrage sur l'Atlantique (ouverture d'un océan et emboîtement des masses continentales conjuguées) ou sur le Pacifique (subductions et traces de «points chauds»). L'unique coupure Mercator de cette nouvelle édition nous a obligé à fixer le mode de centrage. Afin de pallier partiellement cet inconvénient, nous avons choisi le centrage «*océan Pacifique*» (méridien 0° pour les bords E et W) pour la Feuille 1-Physiographie, et le centrage «*océan Atlantique*» (méridien 180° pour les bords) pour la feuille 2-Géologie, afin que le lecteur puisse visualiser les deux modes d'assemblage.
Les échelles et les projections étant identiques, on peut vérifier la superposition de la morphologie des zones sous-marines de la Feuille 1 avec les éléments géologiques de la feuille 2, en utilisant une table lumineuse. **Nota** : Dans le corps du texte, les éléments mis en **caractères gras** correspondent aux différents items qui font l'objet de la légende.

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29 L'abréviation de *milliard d'années* (10^9 ans) est **gA** (de *giga-annum*, appellation officielle des instances géologiques internationales). L'auteur avoue ne pas très bien comprendre pourquoi c'est la forme de l'accusatif singulier « annum»qui a été retenue. L'explication proposée est que l'accusatif se justifierait par l'expression « per annum », qui signifie « par an », ce qui suscite encore plus de perplexité.

FEUILLE - 1 : PHYSIOGRAPHIE, VOLCANS, ASTROBLÈMES

I.1- RELIEF

Publiée pour la première fois à la CCGM, cette Carte montre la totalité de la morphologie de la Terre et notamment celle, moins connue, des zones sous-marines qui représentent presque 71% de sa surface. Au dégradé des couleurs qui traduit le modelé des reliefs, on a rajouté, *uniquement pour les océans*, des indications matérielles de la profondeur sous la forme de fines lignes noires représentant les **isobathes** tous les 1000 m. Par contre, nous n'avons pas gardé les isohypses équivalentes sur les terres émergées (à l'exception de celles des calottes glaciaires du Groenland et de l'Antarctique) car elles oblitèrent par trop le «grain» physiographique des chaînes de montagnes.
L'image du relief (éclairé depuis le NW) a été obtenue à partir d'un modelé numérique terrestre et sous-marin (ETOPO2) selon une grille de 2 minutes de latitude/longitude de résolution. Les données du plancher océanique proviennent de W. Smith & D. Sandwell (1997). Elles sont tirées des observations altimétriques satellitaires combinées à des mesures (plus classiques) de bathymétrie par échosondeur embarqué. Les données des terres émergées sont extraites d'une grille de 30 secondes de résolution provenant des différentes sources de la National Imagery and Mapping Agency (USA).
La compilation des données altimétriques a été réalisée par notre collègue Jacques Ségoufin, malheureusement décédé (8 septembre 2008) avant l'édition définitive de la Carte[30].

I.2- VOLCANS

On a reporté sur cette feuille les **1506 volcans (ou champs volcaniques) actifs ou récents** (pour faire simple, ayant fait éruption au cours des dernières 10 000 années, c. à d. pendant l'époque Holocène), qui ne peuvent être, *a priori*, considérés comme définitivement éteints. Ces systèmes volcaniques sont répartis en 1436 **appareils subaériens** (**triangles rouges**) et 70 **édifices sous-marins** (**triangles bleus**), comme p. ex. le volcan Julia (appelé aussi Ferdinandea ou Graham), près des côtes sud de la Sicile. Chaque triangle est bordé d'un fin liseré blanc qui permet de mieux individualiser les volcans des régions très actives comme dans les arcs insulaires (p. ex. îles de la Sonde) ou dans les arcs-cordillères (p. ex. les Andes). On peut très bien apprécier les hiatus volcaniques de certains arcs, comme celui qui s'étend depuis le Sud de l'Équateur jusqu'au Sud du Pérou, sur quelque 1500 km de long.
Ces volcans ont été extraits du catalogue (arrêté à mars 2006) du *Global Volcanism Program* de la *Smithsonian Institution* (site : *www.si.edu/world/gvp/*).
Le volcanisme fissural qui caractérise l'ensemble des dorsales d'accrétion océanique active (lieu de la divergence des plaques lithosphériques) n'est pas figuré, ici, en tant que tel. Il est représenté, en quelque sorte, par l'axe des dorsales actives (**ligne rouge**) cartographié sur la Feuille 2.

I.3- ASTROBLÈMES

À terre (sauf une seule exception devant la baie de Chesapeake), on a aussi reporté l'emplacement de **198 astroblèmes**, ou cratères d'impact météoritique. On a distingué 2 catégories : cratères de diamètre < 10 km; cratères de diamètre ≥ 10 km; respectivement figurés par des **astérisques noirs** de petite et grande taille.
L'acquisition des données a été arrêtée à avril 2006. Les sources proviennent :

1/ du *Planetary And Space Science Centre* de l'Université du New Brunswick, Canada (John Spray & Jason Hines, site : www.unb.ca/passc/Impact.Database) avec 174 structures;
2/ du site de *Jarmo Moilanen*, Finlande : Impact structures of the World (site : www.somerikko.net/old/geo/imp/impacts.htm), avec 21 structures;
3/ du *NASA/Goddard Space Flight Center Scientific Visualization Studio* pour le cratère Araona/Iturralde (Bolivie), non encore validé;
4/ de Wade S. *et al., in* Lunar and PlanetaryScience, 2002, XXXIII, pour le cratère de Velingara (Sénégal);
5/ de Paillou Ph. *et al., in* C. R. Géoscience, 2004, v; 336, pour la structure de Gilf Kebir (Égypte).

On y a rajouté, bien qu'il ne s'agisse pas d'un cratère d'impact proprement dit, le site de la Tunguska (Sibérie centrale), lieu de l'explosion en altitude d'un astéroïde (comète ?) en 1908 (**cercle évidé rouge**).

I.4- RENSEIGNEMENTS COMPLÉMENTAIRES

Enfin, on a pointé sur cette feuille quelques informations concernant l'altitude des points remarquables : d'abord, les élévations maximales (en mètres) pour chaque masse continentale. On signalera le cas particulier de l'Elburs (5642 m), point culminant du Caucase, frontière géographique traditionnelle entre l'Europe et l'Asie; et aussi du Puncak Jaya (4848 m) dans l'île de Nouvelle-Guinée, géologiquement intégrée au bloc continental australien, et surclassant le mont Kosciusko sur ce même ensemble; puis, les points les plus bas des terres émergées, avec des cotes sous le niveau de la mer, comme la surface de la mer Morte (- 412 m, en voie d'assèchement si l'on laisse la tendance actuelle se poursuivre), lac salé dont le fond atteint la cote négative maximale de – 742 m !
On a aussi privilégié deux grands lacs détenteurs de records mondiaux :
- le Titicaca, sur l'Altiplano andin, le plus haut lac navigable (+ 3810 m; profondeur maximale de 284 m)
- le Baïkal, en Sibérie, le lac le plus profond du monde (1642 m sous un plan d'eau à + 456 m d'altitude) et contenant le plus grand réservoir d'eau douce liquide à la surface de la planète (23 000 km^3).

Le point le plus bas des océans se trouve dans le Sud de la fosse de subduction des Mariannes (– 10 920 m, dans la Challenger Deep). Pour finir, la plus haute montagne du globe terrestre n'est pas l'Everest (+ 8848 m), mais l'île volcanique d'Hawaï (Big Island), avec un dénivelé de 10 239 m, si l'on additionne la cote du sommet de son plus haut volcan (le Mauna Kea, + 4206 m) à la profondeur maximale de sa base sous-marine (– 6033 m).

30 Ancien chercheur à l'Institut de Physique du Globe de Paris, il a été Secrétaire Général de la Sous-Commission « Cartes des Fonds Océaniques»de la CCGM de 1983 à 2004.

FEUILLE - 2 : GÉOLOGIE, STRUCTURE

II.1 - ZONES ÉMERGÉES

II.1.1- Unités chronostratigraphiques

Les zones émergées (29,2 % de la surface de notre planète) correspondant dans leur immense majorité à des formations d'origine continentale (ou continentalisées, dans le cas des arcs insulaires), ont été représentées en utilisant **8** très grandes **unités chronostratigraphiques**[31] : 1=*Cénozoïque*; 2=*Mésozoïque*; 3=*Paléozoïque supérieur*; 4=*Paléozoïque inférieur*; 5=*Néoprotérozoïque*; 6=*Mésoprotérozoïque*; 7=*Paléoprotérozoïque*; 8=*Archéen.* Un certain nombre de regroupements entre ces unités a été opéré quand le contexte géologique ou cartographique le nécessitait. Par rapport à l'édition précédente, nous avons, par souci de cohérence, supprimé le Quaternaire et le Trias («périodes» respectivement incluses dans les «ères» Cénozoïque et Mésozoïque), mais introduit les trois ères de l' «éon» Protérozoïque (unités 5, 6 ,7).

Au sein de ces unités temporelles, on a distingué **3** grands ensembles de **faciès lithologiques** : • formations sédimentaires ou de nature indifférenciée (ou difficile à définir); • formations volcaniques extrusives (**V),** correspondant à un magmatisme exprimé à l'air libre; • formations endogènes (**P**), représentées par des roches formées en profondeur (ayant subi un métamorphisme important ou correspondant des roches magmatiques plutoniques). Les 2 dernières catégories de roches sont caractérisées par un **semis de points** en surimposition (**bleus** pour les extrusives, **rouges** pour les endogènes).

Une seule exception a été faite pour le **volcanisme cénozoïque** (V1) qui se distingue par une teinte uniforme d'un bleu soutenu). En effet, le volcanisme de cette ère (qui inclut celui du Quaternaire et du temps présent) est la conséquence, dans bien des cas (notamment dans le volcanisme de subduction), d'un contexte géodynamique qui perdure jusqu'à nos jours. Il était donc important qu'il soit très nettement perceptible à l'œil et que l'on puisse le mettre aisément en relation avec les volcans «actifs» de la Feuille 1.

Une autre exception a été faite pour les formations les plus anciennes, **archéennes,** («8», antérieures à 2,5 milliards d'années/**gA**), indifférenciées pour des raisons de simplification. On notera que c'est au Canada que les affleurements archéens sont les plus étendus.

II.1.2- Ophiolites

Les ophiolites sont des reliques de croûte océanique (de haut en bas : basaltes sous-marins, gabbros, péridotites) qui, en phase terminale de *subduction* — lors de la collision de deux blocs continentaux (ou continentalisés dans le cas des arcs insulaires) — ont échappé à leur destin habituel de recyclage à l'intérieur du manteau terrestre, pour être piégées au sein de chaînes de montagnes. Elles sont les indices d'un «océan perdu» (Jean Aubouin) et jalonnent de grandes zones de *suture*.

Elles peuvent aussi résulter d'une *obduction*, comme en Oman, où une lame de lithosphère océanique chevauche la bordure d'un socle continental.

À l'échelle de la Carte, les formations ophiolitiques (couleur **vert vif**) ne couvrent généralement que de toutes petites superficies, difficilement perceptibles. Par souci de simplification, nous n'avons retenu, ici, que les ophiolites d'âge méso-cénozoïque (inférieur à 250 millions d'années[32]). On remarquera particulièrement les ophiolites de l'arc des Alpes, des Dinarides/Hellénides, du Zagros (Iran) et de l'Himalaya.

Comme petites îles de nature ophiolitique, on signalera la minuscule île de Gorgona située sur la marge continentale pacifique de la Colombie, et l'île de Macquarie (à un millier de kilomètres au SSW de la Nouvelle-Zélande) qui résulte d'un mouvement de *transpression* qui l'a fait surgir le long de la grande faille transformante dextre (voir note 16) qui sépare l'océan Indien (plaque Indo-Australienne) de l'océan Pacifique (plaque Pacifique), en faisant remonter une lame de croûte océanique cénozoïque. Dans un même registre, on peut aussi citer l'îlot de **Zabargad** (autrefois appelé St Jean/John) en mer Rouge (Égypte), connu depuis l'Antiquité (Egyptiens, Grecs et Romains) pour son intrusion de péridotite renfermant de magnifiques olivines (marqué par un **astérisque vert**).

II.1.3- Grandes provinces magmatiques : les trapps

À certaines périodes de l'histoire de notre planète, des pulsations éruptives de grande ampleur, mais d'une durée qui peut être inférieure 1 million d'années, se sont produites dans les profondeurs du manteau terrestre. Ces «crises» magmatiques ont conduit à de très vastes et volumineux épanchements de basaltes aussi bien à la surface des continents, les **trapps,** que sur le plancher océanique, les «**plateaux océaniques**» (terme forgé par les Anglo-Saxons : *oceanic plateaus*). Ces immenses effusions volcaniques résulteraient de la remontée jusqu'à la base de la lithosphère d'un large panache constituant la tête d'un puissant «*point-chaud»,* dans les premières phases de son fonctionnement (cf. II.2.2.7 et II.3). L'ensemble de ces manifestations en surface sont dénommées, en anglais, «**Large Igneous Provinces**[33] (abrégé

31 Ou découpage du temps géologique. Dans le tableau de la légende correspondant, ainsi que dans celui des âges de la croûte océanique (cf. II.2.2.1), les datations indiquées sont celles qui ont été validées par la Commission Internationale de Stratigraphie dans son *Échelle des Temps Géologiques* publiée en 2008. Pour simplifier, nous n'avons pas mentionné la marge d'incertitude (2σ).

32 L'abréviation de *million d'années* (106 ans) est **Ma** (de «mega-annum»), voir note 1).

33 Ce terme et surtout son abréviation LIP sont d'un usage très courant dans la communauté internationale des géosciences; ils ont été proposés en 1994 par Millard Coffin et Olav Eldholm. *Rev. Geophysics*, 32 :1-36.

en **LIP**), i.e. «Grandes Provinces Magmatiques». Les laves de trapps, très fluides, sont aussi appelées en français «basaltes de plateaux»; en anglais, le terme utilisé est plus imagé, «flood basalts» (basaltes d'inondation».

Dans les précédentes éditions, les trapps étaient «noyés» dans les trop grandes tranches temporelles des unités chronostratigraphiques retenues pour la Carte (p. ex. Paléozoïque supérieur pour les trapps de *Sibérie,* ou Mésozoïque pour ceux du *Deccan,* en Inde). Par ailleurs, un certain nombre de trapps se trouvent précisément à cheval sur les grandes coupures qui bornent ces unités : p. ex. limite Paléozoïque/Mésozoïque (250 Ma) en Sibérie; limite Mésozoïque/Cénozoïque (65,5 Ma, aussi appelée limite K/T, c. à d. Crétacé / «Tertiaire»[34]) pour le Deccan. Cette coïncidence n'est peut-être pas fortuite puisque pour un certain nombre de géologues (cf. p. ex. Courtillot et collaborateurs), les grandes *extinctions en masse* ayant affecté les organismes vivants[35] seraient imputables à l'émission massive de gaz et d'aérosols nocifs délivrés par ces gigantesques éruptions. Cette hypothèse est toutefois concurrencée par (mais a été aussi plus tardivement associée à) celle faisant intervenir l'impact de grandes météorites, comme celle de Chicxulub dans le Nord du Yucatan, au Mexique, pour la limite K/T (voir Feuille 1).

Pour pallier ces deux inconvénients, nous avons choisi, pour cette nouvelle édition, d'attribuer à tous les **trapps** la même couleur (**rouge orangé vif**), avec l'indication, en noir, de leur âge moyen en **Ma** (p. ex. «16 Ma» pour les trapps de *Columbia River/Snake River*, dans le NW de Etats-Unis). On remarquera ainsi que les trapps du *Parana*, au Sud du Brésil, ont le même âge (133 Ma, partie basale du Crétacé) que ceux, de surface plus réduite, d'*Etendeka*, en Namibie. Ces deux ensembles qui ne formaient qu'une seule entité sont maintenant séparés par plusieurs milliers de kilomètres. Initialement produits par le «point-chaud» de Tristan da Cunha (HG, voir la liste dans la marge inférieure de la Feuille 2), ils se sont éloignés l'un de l'autre lors de l'ouverture de l'Atlantique Sud qui a débuté peu après, au cours du Crétacé inférieur. En Afrique australe, non loin des trapps d'Etendeka, affleure un autre ensemble de trapps, ceux du *Karoo,* un peu plus anciens (183 Ma, Jurassique inf.), que l'érosion a ultérieurement démembrés. La troisième grande «LIP» d'Afrique, est celle des trapps d'*Éthiopie* (30 Ma, Oligocène) qui incluent ceux du *Yémen* qui n'en sont séparés que par l'entrée de la mer Rouge (détroit de Bab el Mandeb). Presque contemporains du Karoo, des résidus des trapps de *Ferrar* (175 Ma) associés à des sills du même âge (marqués par des **astérisques roug**es de même teinte sur la projection polaire antarctique), sont disséminés le long de la grande chaîne des monts Transantarctiques. La proximité temporelle et géographique (lorsque ces deux ensembles étaient inclus dans le mégacontinent Gondwana) laisse à penser qu'ils pourraient avoir été engendrés par un même point chaud. Deux petits affleurements de trapps situés au NE de ceux du Deccan ne font pas partie de cet ensemble. Il s'agit de ceux de *Rajmahal* (118 Ma, Crétacé inférieur) à la pointe NE du bouclier indien, et de *Sylhet* (116 Ma), un peu plus à l'Est, près de la frontière Assam/Bangladesh. Le point chaud originel pourrait être celui des Kerguelen (HI). Ce dernier aurait ensuite édifié la ride Nonantest (en anglais : Ninetyeast Ridge, ou 90° E Ridge, cf. II.2.2.7). Un autre ensemble est celui des trapps d'*Emeishan* qui s'est formé en Chine vers 260 Ma (au Paléozoïque, à la limite Permien moyen/Permien supérieur).

En ce qui concerne les immenses trapps de ***Sibérie*** mentionnés plus haut, ses affleurements actuels couvrent essentiellement une partie de l'Est du craton sibérien et on en retrouve des témoins plus au Nord, dans la partie sud de la péninsule de Taymir (visible seulement sur la projection polaire arctique). À l'origine, ces trapps couvraient une superficie beaucoup plus grande (que certains estiment à quelque 4 millions de km^2, voire plus). Le **tireté-point rouge**, dessiné sur la grande plaine de Sibérie occidentale, correspond à une estimation minimale de leur extension vers l'Ouest, sous les dépôts sédimentaires méso-cénozoïques (Reichow *et al.*, 2002).

Enfin, nous avons fait figurer (**tireté simple rouge**) les limites (que l'on peut suivre dans l'Est de l'Amérique du Nord, le NE de l'Amérique du Sud, et l'Ouest de l'Afrique et de l'Europe; tracé d'après J.G. McHone, 2003) d'une grande province magmatique d'un seul tenant. Il s'agit des trapps de la ***CAMP*** (de l'anglais, *Central Atlantic Magmatic Province*) qui ont été formés à partir d'un point-chaud, il y a 200 Ma (limite Trias/Jurassique) peu avant que l'ouverture de l'Atlantique Central ne désarticule cet ensemble. L'érosion en a fait disparaître l'empilement des coulées de lave, mais la CAMP a pu être reconstituée grâce aux sills et dykes (corps volcaniques intrusifs), à l'origine sous-jacents aux émissions de surface.

Un dernier point concernant ce domaine des LIP continentaux reste à expliciter. Les îles des **Seychelles** proprement dites sont constituées de granites du Néoprotérozoïque (**P5**) indiqués par une flèche, car ces îles sont à peine discernables sur la Carte. Les granites sont recoupés par des dykes datés à 65 Ma (pointés aussi par une flèche, avec un **astérisque rouge**). Cela confirme bien que le *microcontinent* des Seychelles était soudé à l'Inde au moment de l'émission des trapps du Deccan.

II.1.4- Glaciers, inlandsis

Les glaciers d'une certaine ampleur ont été cartographiés dans l'extrême Sud des Andes, ainsi que ceux des îles de l'extrême Nord canadien et eurasiatique. On leur a attribué la même teinte que celle des **calottes glaciaires** du Groenland et de l'Antarctique (**grisé très clair**). Sous ces deux derniers *inlandsis*, le **contour de la cote zéro** (niveau de la mer) a été dessiné. Ces zones du substratum rocheux sous-glaciaire abaissé par la surcharge de la calotte sont représentées par une teinte plus foncée (**violet clair**) que celle de la calotte.

34 L'utilisation du terme de «Tertiaire» qui correspondait au Cénozoïque amputé du Quaternaire, est désormais déconseillée.

35 Les grandes coupures chronostratigraphiques (ères, périodes, époques) ont précisément été créées (depuis le XIXè siècle) à la suite de l'observation de changements brusques, très importants et généralisés, dans l'association des fossiles et microfossiles contenus dans les dépôts sédimentaires, essentiellement marins.

II.1.5- Éléments structuraux

Sur les terres émergées, ne figurent que deux éléments structuraux à l'exception de l'Islande (cf. II.1.6), de l'Afar (II.2.2.4), et du Makran (II.2.2.6); les grandes **failles normales** ou **de nature non précisée** (**trait noir simple**); les grands **fronts de chevauchement** (**trait noir dentelé**) ceinturant notamment les grandes chaînes orogéniques : «alpines» (p. ex. Alpes-Carpates, Caucase, Himalayas, Maghrébides, Rocheuses, Andes) ou plus anciennes, hercyniennes (= varisques : Oural, etc.), calédoniennes (Appalaches, Nord des îles Britanniques, Ouest de la Scandinavie,…) ou même, racines des chaînes précambriennes (bouclier canadien, etc.).

Parmi les nombreux grands linéaments structuraux, on n'en relèvera que quelques-uns, pris un peu au hasard:

— Une ligne qui part du Sud de la Norvège et qui se termine en mer Noire (ligne de Tornquist-Teisseyre) qui sépare l' «Éo-Europe précambrienne» englobant le bouclier Baltique (plus correctement appelé Fenno-scandien) et les affleurements archéens et protérozoïques d'Ukraine, d'une marqueterie européenne (Paléo-, Méso-, Néo-Europe) plus récente.

— Le système de rifts continentaux, formé à partir de l'Oligocène, qui traverse tout l'Ouest de l'Europe, depuis le Nord de la mer du Nord jusqu'au golfe du Lion, en passant par la vallée du Rhin et le couloir rhodanien. Il est ponctué localement par des épanchements volcaniques (notamment Vogelsberg et Eifel en Rhénanie-Hesse, et Cantal et chaîne des Puys en Auvergne).

— Le grand graben de l'Amazone, isolant les deux socles guyanais des boucliers brésiliens proprement dits (Central-Amazone et São-Francisco).

— Un grand accident ancien transversal SW-NE, coupant l'Afrique en deux, depuis le golfe de Guinée jusqu'à la partie médiane de la mer Rouge.

— Le système des grands rifts de l'Est-Africain qui s'est mis en place au Cénozoïque, en relation avec le point-chaud de l'Afar (H1) et l'ouverture du golfe d'Aden et de la mer Rouge. Les rifts sont souvent occupés par des grands lacs : du Nord au Sud, lacs Turkana, Albert, Edward, Kivu, Tanganyika, Malawi, et jalonnés par un volcanisme important. Si cette expansion continentale se poursuit, le rift se transformera progressivement en une zone océanique du type «mer Rouge», puis «golfe d'Aden», isolant complètement une plaque «Somalie» du reste de l'Afrique, nommé plaque «Nubie» par certains géologues.

— Les grandes failles qui, depuis le Pamir, lacèrent en éventail la Chine et l'Asie du SE. Elles ont joué en coulissement en réponse à la poussée continue de l'Inde sous l'Est du bloc eurasiatique depuis quelque 50 millions d'années, et en découpant de grands bassins comme celui du Tarim (au Xin Jiang ou Turkestan chinois) : p. ex. failles de l'Altyn Tagh (SW-NE) et du Kunlun (W-E).

— Retournant en Afrique, on notera l'existence du «grand dyke du Zimbabwe», bande étroite de Paléoprotérozoïque intrusif d'orientation N-S, longue d'environ 550 km, avec une largeur maximale ne dépassant pas une dizaine de kilomètres.

II.1.6- Le cas de l'Islande

L'Islande, qui couvre une superficie importante (103 000 km²), est une île entièrement volcanique, d'origine uniquement océanique. Elle s'est édifiée sur un substratum de croûte océanique modifiée par un puissant point chaud (marqué HD sur cette feuille) lié à l'ouverture de l'Atlantique Nord (au Nord de 60°N). L'île est traversée par l'axe de la *dorsale* (d'expansion) *medio-Atlantique* qui la partage en deux domaines distincts : la plaque Europe, à l'Est, et la plaque Amérique du Nord, à l'Ouest. Au lieu de cartographier l'île comme le reste des terres émergées (en l'occurrence en «V1»), à l'instar des éditions précédentes, nous avons choisi de la représenter comme une surface de croûte océanique où l'on distingue des basaltes plio-quaternaires, puis miocènes, de part et d'autre de l'axe d'accrétion océanique.

II.2 - ZONES SOUS-MARINES

L'océan mondial constitue plus des 2/3 de la surface de notre globe (70,8 %). Il recouvre d'une part, les bords des masses continentales, appelés *marges continentales*, et d'autre part, les fonds marins dont le substratum est formé de *croûte océanique* «fabriquée» à l'axe des *dorsales d'accrétion océanique*, appelées aussi «*rides médio-océaniques*». La profondeur moyenne de l'océan est de 3700 m, une valeur bien supérieure à l'altitude moyenne des continents qui est de 800 m. Le dessin de la maquette de la partie sous-marine de cette Feuille 2, a été réalisé ou contrôlé, pour certains éléments (axes des dorsales d'accrétion, failles transformantes/zones de fracture, axes des fosses de subduction, plateaux océaniques, traces de points-chauds et autre reliefs «anormaux»), en superposant cette feuille à la maquette «Physiographie» .

II.2.1- MARGE CONTINENTALE

II.2.1.1- Limite continent/océan (COB)

Sur la Carte, la limite entre croûte continentale et croûte océanique (en anglais **COB**, i.e. Continent/Ocean Boundary) est marquée par un **trait d'un bleu**, visible le long des *marges continentales passives*, nées du rifting lors de la séparation de deux blocs continentaux qui, en s'éloignant l'un de l'autre, ont laissé la place à un océan. Dans la réalité, cette limite n'est pas toujours très nette et l'on doit plutôt parler d'une zone de transition entre une croûte continentale bien identifiable et une croûte océanique «normale» caractérisée par des anomalies magnétiques bien répertoriées. La zone de transition montre souvent de la croûte continentale étirée, très amincie, injectée de péridotites (exhumation) du manteau sous-jacent.

Le long des *marges continentales actives*, caractérisées par une *zone de subduction*, la limite COB est nette (axe de la fosse de subduction) et le trait bleu est complètement masqué, cartographiquement, par le tracé symbolisant la subduction (cf. II.2.2.6).

> Étant donné les implications juridiques (et donc politiques et économiques) que suscite la délimitation de la COB dans le cadre de la formulation de la *Convention des Nations Unies sur le Droit de la Mer (UNCLOS)*, nous tenons à souligner que la limite dessinée sur cette Carte n'est qu'une approximation, parfois assez conjecturale, et qu'elle ne saurait en aucun cas revêtir un caractère juridique.

II.2.1.2- Microcontinents

On observera sur cette feuille, quelques «îlots» ou «radeaux» de croûte continentale (donc entourés de la **ligne bleue** caractéristique) isolés au sein d'un bassin océanique. Ce sont des *microcontinents* qui résultent des vicissitudes de l'ouverture d'un océan. C'est le cas, notamment, de la plateforme des Seychelles, dans l'océan Indien; du microcontinent de Jan Mayen, dans l'extrême Nord de l'Atlantique; du haut-fond de Bollons (60° S, 177° W) au large de la marge continentale de la Nouvelle-Zélande, dans le Pacifique; ou du microcontinent, détaché de la pointe de la péninsule Antarctique, qui abrite l'archipel des South Orkneys (Orcades du Sud).

En revanche, nous n'avons plus retenu, pour cette édition, la nature continentale de l'Agulhas Bank (ou banc des Aiguilles, 25°E, 40°S), au Sud de l'Afrique du Sud, sur la base de travaux plus récents qui tendent à prouver qu'il s'agit en fait d'une grande morphostructure d'origine volcanique établie sur croûte océanique, comme les autres grands reliefs du SW de l'océan Indien.

II.2.1.3- Arcs insulaires

Les arcs insulaires sont traités cartographiquement comme les continents et délimités par le même **trait bleu**. En effet, ils sont le résultat des processus magmatiques propres à la *subduction* qui ont conduit à la «*continentalisation»* de leur croûte (devenant notamment plus épaisse et plus légère que la croûte océanique). Il est probable qu'un certain nombre d'entre eux, comme l'archipel du Japon, aient vu leur substratum se détacher du continent qui leur fait face, suite à une particularité bien connue du processus de subduction («roll-back» du «slab») qui fait s'ouvrir un bassin *arrière-arc* (cf. II.2.2.4 et II.2.2.6).

II.2.1.4- Plateau continental

Les *plateaux continentaux* («plateformes continentales» ou encore «terrasses continentales») constituent la partie la plus interne des marges continentales. Ils s'étendent entre le rivage et la rupture de pente au-delà de laquelle descend le *talus continental* (ou «pente continentale»). La limite externe de cette terrasse se situe en moyenne vers –132 m. Pour des raisons de commodité et d'échelle de la Carte, c'est **l'isobathe -200 m** qui a servi ici (et sert communément) a délimiter le plateau continental, car cette profondeur n'est jamais très éloignée de la rupture de pente. Sur cette feuille et du point de vue de l'expression cartographique, le plateau continental n'est traité que du seul point de vue morphologique (terrasse), et masque toutes les autres unités cartographiques qu'il pourrait recouvrir. C'est ainsi que le plateau «continental» du delta du Niger oblitère la nature océanique de la croûte sous-jacente sur laquelle l'alluvionnement du grand fleuve africain prograde (i.e. s'édifie en s'avançant vers le large). On peut faire le même genre de remarque pour le plateau «continental» de l'Islande, île issue d'un volcanisme entièrement volcanique (cf. II.1.6).

L'ensemble des plateaux continentaux (et d'arcs insulaires) représente environ 7,5 % de la surface des océans. Sur la Carte, le plateau continental est représenté en **beige clair.** On signalera que l'on a inclus dans cette unité cartographique, les terrasses des atolls ou des îles volcaniques qui ne sont pas «génétiquement» continentaux, mais d'origine purement océanique (p. ex. l'archipel des Tuamotu). C'est d'ailleurs une commodité sémantique très répandue qui s'est généralisée par la formulation du droit de la mer. Très réduite le long d'un bon nombre de côtes africaines (quelques kilomètres devant Mogadishu, Somalie) ou des rivages brésiliens au Sud de l'équateur, la plateforme n'est pas non plus très développée sur les arcs insulaires. En revanche, elle est très étendue au large des côtes de l'Asie du SE (mer de Chine Orientale, plateforme de la Sonde), de la Patagonie argentine (jusqu'à 600 km de largeur) et l'on observe une extension maximale sur la façade arctique de l'Eurasie du Nord (jusqu'à quelque 900 km sur le plateau continental de Sibérie orientale).

La cartographie du plateau continental est une innovation de cette 3ème édition. C'est un élément important pour la paléogéographie récente. Il permet d'apprécier le recul du niveau marin qui a eu lieu lors de la *grande régression du Würm* (il y a environ 20 000 ans), dernier maximum glaciaire au cours duquel le niveau de la mer a baissé de près de 130 m. Au cours de cet événement, la masse d'eau soutirée aux océans a servi à édifier d'énormes calottes glaciaires sur le Nord de l'Amérique du Nord (jusqu'à 4 km de glace au-dessus de la baie d'Hudson) et le NW de l'Eurasie. À cette époque, la Manche et ses approches occidentales étaient complètement émergées, et l'on pouvait aller à pied sec du fond du golfe du Siam jusqu'à Bali, ou faire de même entre la Nouvelle-Guinée et l'Australie.

II.2.1.5- Talus continental

La partie de la marge continentale située en bas de la plateforme jusqu'au contact avec la croûte océanique (i.e. jusqu'à la COB) est appelée *talus continental* (ou «pente continentale»). Cela concerne aussi l'armature des arcs insulaires, comme expliqué plus haut. Cet élément de morphologie sous-marine est représenté par une couleur d'un **vert jaunâtre pâle**, plus sombre que celle du plateau continental. Le talus continental peut parfois se déployer largement, en particulier au Sud de l'Amérique du Sud où l'éperon qui porte les Malouines/Falkland se projette vers l'Est, en direction de l'arc des Sandwich du Sud (autrefois dénommé Antilles du Sud), sur plus de 1500 km.

II.2.1.6- La marge Antarctique

La marge continentale de l'Antarctide présente des caractéristiques morphologiques particulières à cause de la surcharge isostatique exercée sur la lithosphère du continent par son énorme calotte glaciaire qui, existe depuis environ 30 Ma : présence fréquente d'une dépression à proximité de la côte (pouvant atteindre 1000 m de profondeur), et plateforme continentale inhabituellement abaissée (de – 400 à – 700 m) avant d'arriver à la rupture de pente. Plateau continental et talus continental n'ont donc pas été différenciés ici et ont été regroupés sous une même **tonalité vert jaunâtre très clair,** différente de celle qui a été attribuée au talus continental.

II.2.1.7- Plateforme de glace

Une *plateforme de glace* (ou «plateau glaciaire»; en anglais, «ice-shelf») est, pour les glaciologues, un volume de glace de l'inlandsis qui a flué («coulé» lentement) au-delà du trait de côte et s'étend, sous la forme d'un glacier plat flottant au-dessus de la terrasse continentale. Son épaisseur peut varier de 100 à 1000m. Ces plateformes sont caractérisées sur la Carte par une **couleur gris-bleu**. N'ont pas été prises en compte sur la Carte, les plateformes de glace du Groenland, ni celles des îles arctiques du Canada, trop petites pour l'échelle de la Carte. Celles de l'Antarctique ont une superficie cumulée d'environ 1,5 millions de km^2, mais elles sont menacées par le réchauffement climatique. Les plus grandes plateformes sont celles de Ronne, au «Nord», et de Ross, au «Sud» qui emprisonne partiellement l'île éponyme qui abrite le volcan actif Erebus (cf. Feuille 1).

Il ne faut pas confondre plateforme glaciaire avec *banquise*; celle-ci n'est qu'une mince couche de glace (quelques mètres) appelée «glace de mer», car résultant de la congélation de l'eau de mer. La superficie de la banquise fluctue considérablement au gré des saisons.

II.2.2- BASSINS OCÉANIQUES

Les bassins océaniques, c'est-à-dire la partie du fond des océans dont le substratum basaltique (recouvert de sédiments, sauf dans les zones axiales des dorsales d'accrétion océanique) est formé de croûte océanique. Leur histoire et leur structure diffèrent complètement de celles des continents. Ils occupent environ 59 % de la surface de la planète. On y distingue cinq grands types de morphostructures : • les plaines abyssales; • les dorsales (ou rides) d'accrétion océanique; • les grandes zones de fracture; • les fosses de subduction; • les reliefs océaniques «anormaux», i. e. des structures d'origine volcanique dont la genèse est postérieure à la croûte océanique sur laquelle ils ont été édifiés.

II.2.2.1- Âge de la croûte océanique

En regard de l'ancienneté des continents dont les noyaux affleurants les plus vieux ont été datés de quelque 4 Ga (milliards d'années), les bassins océaniques ont un substratum dont l'âge est toujours inférieur à 200 Ma (millions d'années). Dans l'état actuel des connaissances, les âges les plus anciens ont été rapportés au Jurassique moyen (qui débute à 175,6 Ma) : devant la marge orientale des États-Unis d'Amérique, devant sa marge conjuguée d'Afrique occidentale (les 2 marges s'emboîtaient l'une dans l'autre avant l'ouverture de l'Atlantique Central) et dans l'Ouest du Pacifique Central. En effet, la *Terre ayant un volume constant* [36], tout élément de croûte océanique formé à l'axe des dorsales antérieurement à cette époque a nécessairement été «avalé» par la subduction, ou piégé à l'état de lambeau au gré des collisions continentales ou bien lors de la mise en place d'une obduction (cf. II.1.2)

La cartographie de l'âge de la croûte océanique a été obtenue en interpolant la position des anomalies magnétiques qui résultent de l'inversion périodique du champ magnétique terrestre (cf. Müller *et al.*, 1997), de manière à ne faire apparaître que les limites des unités chronostratigraphiques retenues : *Plio-Quaternaire – Miocène – Oligocène – Éocène – Paléocène – Crétacé supérieur – Crétacé inférieur – Jurassique supérieur - Jurassique moyen* (cf. le tableau de la légende correspondant). L'échelle des teintes utilisée pour ces unités océaniques est celle qui est communément utilisée par la CCGM.

Pour les bassins enclavés comme en Arctique, issus de l'ancien océan Téthysien (Méditerranée orientale), ou d'arrière-arc, où l'âge de la croûte n'est parfois pas connu avec précision, on a fixé une fourchette d'âge plus large (p. ex. Jurassique-Crétacé indifférencié pour la Méditerranée Orientale, ou Néogène pour le bassin marginal du Sud de la mer

36 À partir de la fin des années 1950, le géologue australien Samuel Warren Carey, avait soutenu l'hypothèse d'une Terre dont le volume serait en expansion continue depuis les derniers 200 Ma, pour expliquer l'éclatement du supercontinent Pangée et la « dérive»subséquente des continents actuels. De ce fait, il niait l'existence des zones de subduction. Cette théorie a été (presque) définitivement abandonnée.

de Banda, Indonésie). Par ailleurs, en l'absence d'un nombre suffisant d'unités chronostratigraphiques successives et de teinte bien identifiable, la couleur de l'âge du substratum océanique, de ces régions de superficie relativement réduite, peut induire quelque doute. L'âge est alors précisé par le symbole indiqué en légende (p. ex. «j3» pour le bassin sud-Caspienne, ou «g» pour le bassin des Célèbes).

Enfin, il existe un certain nombre de secteurs océaniques où les anomalies magnétiques n'ont pu être identifiées par les géophysiciens, et donc où **l'âge de la croûte est indéterminé**. Ils ont été cartographiés en **gris**. On les trouve essentiellement autour de l'Antarctique, et à l'Est et au SE de l'Australie.

II.2.2.2- Plaines abyssales

Avec un fond très plat, et tapissé de sédiments souvent épais, les plaines abyssales s'étalent de part et d'autre des dorsales d'accrétion océanique. Leur profondeur (tonalités bleues sur la physiographie de la Feuille 1) croît insensiblement de quelque 4000 m à un peu plus de 6000 m. Schématiquement, plus on s'éloigne de l'axe des dorsales qui ont généré leur substratum basaltique, plus l'âge, la densité et la profondeur de ce dernier augmentent. Parallèlement, l'épaisseur du recouvrement sédimentaire croît avec l'éloignement de la dorsale[37]. Un bel exemple de plaine abyssale bien individualisée et non perturbée par des reliefs parasites, est illustré par le bassin Argentin, bien cadré par la dorsale d'expansion de l'Atlantique Sud, l'éperon des Falkland/Malouines et la marge continentale d'Argentine, et dont le centre s'abaisse à plus de 6000 m de profondeur.

II.2.2.3- Dorsales d'accrétion océanique

Les *dorsale*s (ou *rides*) *d'accrétion océanique* forment la plus grande chaîne de montagnes du monde avec une longueur cumulée de près de 80 000 km [38] sinuant à travers les quatre océans. Partant de la base de la marge continentale du delta de la Lena (Sibérie orientale) dans l'Arctique, ce système traverse l'Atlantique dans toute sa longueur, pénètre dans l'océan Indien (avec une branche aboutissant en mer Rouge[39], formant ainsi un «point-triple» de dorsales au SE de la Réunion), puis contourne, par le Sud, la Nouvelle-Zélande, pour entrer dans le Pacifique. Dans cet océan, la dorsale n'occupe pas une situation médiane, mais est décalée vers l'Est (elle est alors appelée *dorsale Est-Pacifique*), avant de «mourir» dans le golfe de Californie (ou mer de Cortes). De cette longue ride, partent deux rameaux pointés vers l'Amérique du Sud : la *dorsale Sud-Chili* et la *dorsale des Galapagos*. Plus au Nord, on trouve la *dorsale de Juan de Fuca* qui fait face aux côtes qui vont du Nord de la Californie à la Colombie Britannique. Cette petite dorsale est reliée à celle du golfe de Californie par la faille transformante (cf. II.2.2.5) de San Andreas. Ces deux dernières dorsales ne formaient qu'un seul ensemble avant que le tronçon maintenant manquant n'ait été absorbé par la subduction sous l'actuelle Californie.

Les dorsales océaniques, larges de 1000 à 3000 km, s'élèvent de 2500 à 3000 m au-dessus des plaines abyssales; avec une crête qui culmine en moyenne vers 2500 m de profondeur. Elles occupent près du tiers de la surface des fonds marins.

La dorsale medio-Atlantique, avec son allure sinueuse semblable à celle des deux marges continentales conjuguées dont elle a provoqué la «dérive», est un exemple très pédagogique illustrant l'expansion océanique.

II. 2.2.4- Axe de dorsale d'accrétion océanique

L'axe des dorsales d'accrétion océanique actives constitue la *frontière entre deux plaques lithosphériques divergentes*. Cette dernière est marquée par une *activité sismique*. Les axes sont représentés par un **trait rouge** continu, couleur qui rappelle le fait qu'ils sont un élément essentiel du volcanisme terrestre puisqu'ils *produisent du magma* en continu, géologiquement parlant. Selon que *le taux de divergence* [40] est faible ou fort, la morphologie de la ride diffère. Avec des vitesses d'ouverture faibles (2 à 3 cm/an), comme en Atlantique, le relief est accidenté avec une vallée profonde (rift). Avec des vitesses rapides (autour de 15 cm/an), comme dans la dorsale Est-Pacifique, la topographie est beaucoup plus adoucie, avec absence de vallée axiale profonde. Ce contraste est très perceptible sur la Feuille 1 (Physiographie).

Le cas particulier de l'*Islande*, avec ses rifts d'accrétion océanique à l'air libre, a été évoqué plus haut (II.1.6). Quant au «triangle» de l'*Afar* (également situé au-dessus d'un point-chaud, marqué HA), c'est un «point triple» où convergent le golfe d'Aden (prolongement de la dorsale active de Carlsberg, dans la moitié nord de l'océan Indien), le rift océanique de la mer Rouge, et le grand Rift Est-Africain. Dans l'Afar, le substratum est encore continental, mais on y a tracé, un peu schématiquement, 3 petits segments d'axe d'accrétion actifs, prémices (possibles) d'une future océanisation (si le contexte géodynamique actuel ne subit pas de modifications majeures, cf. II.1.5).

En ce qui concerne les *bassins arrière-arc* (ou «bassins marginaux») qui s'ouvrent «derrière» un arc insulaire (i. e. du côté opposé à la fosse de subduction), un mini-océan se forme et l'axe d'accrétion océanique est représenté par le **même trait rouge** que pour les océans : voir p. ex. le *bassin marginal* de l'arc *des Mariannes* (Pacifique Ouest), ou le *bassin*

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37 Elle peut atteindre plusieurs milliers de mètres à l'approche du pied de certaines marges continentales, notamment de celles qui sont alimentées par l'apport de grands fleuves charriant une très forte charge sédimentaires (Amazone, le système Gange/Brahmapoutre, Indus,…)

38 La longueur se réduit à environ 60 000 km quand on ne prend en compte que la longueur des segments d'axe d'accrétion océanique.

39 Cette branche se dirige d'abord vers le Nord avec la dorsale Centrale Indienne, oblique ensuite vers le NW avec la ride de Carlsberg, puis s'engage franchement en direction de l'Ouest avec la dorsale du golfe d'Aden, avant de se raccorder de manière complexe, via la zone de l'Afar, avec la mer Rouge.

40 Les chiffres correspondent à des valeurs moyennées sur une certaine durée; ils ne signifient nullement que, régulièrement, chaque année, se produit un écartement, et encore moins à la vitesse indiquée.

de Lau qui s'ouvre derrière l'arc des Tonga (Pacifique SW), ou encore le *bassin arrière-arc des Sandwich du Sud* (anciennement dénommées «Petites Antilles Australes»), un des jalons de la boucle qui relie les Andes méridionales à la péninsule Antarctique. On observera un stade tout à fait préliminaire de formation d'un bassin arrière-arc, le *bassin d'Okinawa*, à l'Ouest de l'arc insulaire des Ryukyu (extrême Sud du Japon), avec une succession de petits segments actifs, en échelon, qui commencent à découper la marge continentale de la mer de Chine Orientale. On trouve un stade un peu plus évolué dans le *bassin marginal* (très étroit) *de Bransfield*, localisé en arrière de la zone de subduction des Shetland du Sud, au sein de la péninsule Antarctique.

Les **axes d'accrétion océanique fossile** sont représentés comme les axes actifs, (mais en **tireté rouge**), comme p. ex. dans la mer de la Scotia (entre Amérique du Sud et Antarctide), ou en mer de Tasman (à l'Est de l'Australie). Ce sont des lieux où la divergence a cessé de fonctionner à l'intérieur d'un océan ou d'un bassin arrière-arc. Un des exemples les plus intéressants est celui de l'Atlantique Nord qui a commencé à s'ouvrir entre le Canada et le Groenland, au Paléocène, puis a hésité entre l'Ouest et l'Est du Groenland à l'Éocène. Mais cette divergence s'est arrêtée de fonctionner dans la mer du Labrador et le bassin de Baffin, et l'ouverture a continué à l'Est, en éloignant définitivement le Groenland du NW de l'Europe. La mer du Labrador est un océan qui a avorté, et le Groenland, après s'être dissocié de la plaque Amérique du Nord, l'a finalement réintégrée.

II.2.2.5- Faille transformante, zone de fracture

Un des traits caractéristiques de la morphologie des bassins océaniques est leur lacération par un réseau de longues failles (**traits noirs** sur la Carte) recoupant perpendiculairement les dorsales d'accrétion océanique. Entre les extrémités de deux segments d'axe actif, la faille est elle-même active et joue en décrochement (ce qui produit une *activité sismique*). Cette partie est appelée **faille transformante.** Au delà, il n'y a plus de coulissement entre les deux bords de l'accident et la faille est sismiquement inactive; elle représente en quelque sorte la cicatrice de la faille transformante. On a alors affaire à une **zone de fracture**. Ce type de faille complexe[41] atteint facilement une longueur de plusieurs milliers de kilomètres.[42] Comme l'on peut s'y attendre, les plus grandes zones de fracture (quelque 6000 km) se trouvent dans l'océan Pacifique : zones de fracture de Mendocino (touchant le cap du même nom, près de la frontière entre la Californie et l'Oregon), de Clipperton, du système de l'Eltanin (entre la péninsule Antarctique et la marge continentale de la Nouvelle-Zélande), etc. Les zones de fracture sont des marqueurs de la rotation entre deux plaques divergentes. Le plus bel exemple en est fourni par la grande fracture qui joint l'extrémité méridionale de l'Amérique du Sud à la pointe de l'Afrique australe. Ce tracé, en arc de cercle presque parfait, permet de suivre l'ouverture en éventail de l'Atlantique Sud.

Un exemple de faille transformante importante est la faille d'Owen, dans le NW de l'océan Indien, qui décale la dorsale active du golfe d'Aden par rapport à celle de Carlsberg[43] (située au milieu de la moitié nord de cet océan), puis relie ce système d'accrétion océanique à la zone de subduction du Makran, le long des côtes des Baluchistans pakistanais et iranien. La faille «*transforme»* donc un mouvement de divergence en un mouvement de convergence (cf. aussi II.2.3.6). Cet accident SW-NE se termine devant Karachi, juste en face du front de chevauchement des chaînes qui bordent l'ouest de la vallée de l'Indus, et qui se raboutent aux chaînes de collision himalayennes. La faille transformante d'Owen, qui joue en décrochement (coulissement) dextre[44], constitue la *frontière entre les plaques* Indo-Australienne et Arabie.

Sur cette Feuille 2, nous n'avons reporté que quelques exemples (22 **doubles demi-flèches noires de sens opposés**) du **mouvement de** grandes **failles transformantes** (ou simplement décrochantes) aussi bien au sein d'un océan que sur un continent. On citera seulement 3 exemples : - les failles transformantes qui constituent les frontières nord (sénestre) et sud (dextre)de la plaque Caraïbe; - la faille transformante dextre de *San Andreas* (*sensu lato*) qui fait suite au système en ouverture du golfe de Californie, coupe à travers tout l'Ouest de la Californie pour ressortir au cap Mendocino et rejoint l'axe d'accrétion qui borde la plaque de Juan de Fuca; - la faille sénestre *du Levant* qui joint la mer Rouge à la zone de collision de la plaque Arabie contre l'Anatolie, et dont la forme en baïonnette ouvre les petits bassins[45] de la mer Morte et du lac de Tibériade.

II.2.2.6- Zone de subduction, fosse de subduction, autres fosses

Les zones de subduction, comme toute *frontière de plaques*, sont *sismiquement actives*[46]. Mais ici, dans un contexte de *convergence*, la lithosphère océanique (plus lourde) d'une plaque «subduite»[47] plonge suivant un plan plus ou moins incliné (panneau ou «slab»), sous le bord d'une plaque supérieure (chevauchante) dont la lithosphère comprend une

41 Pour les auteurs anglo-saxons, les termes de *transform fault* et *fracture zone* «sont parfaitement synonymes», avec une plus grande fréquence d'utilisation pour le second dans le sens de «expression géomorphologique d'une faille transformante prise dans sa totalité» (J. M. Vila, 2000).

42 En géométrie, tout mouvement sur une sphère peut être assimilé à une rotation dont l'axe passe par le centre de la Terre; les zones de fracture suivent donc des petits cercles centrés sur les pôles de rotation des plaques (qu'il ne faut pas confondre avec les Pôles de l'axe de rotation de la planète).

43 Voir note 11.

44 On définit le jeu d'un décrochement en se «plaçant»sur l'un quelconque de ses bords et en observant la direction vers laquelle se déplace le compartiment opposé : si c'est vers la droite, le mouvement est *dextre*; si c'est vers la gauche, il est *sénestre*.

45 Ces petits bassins de décrochement sont plus communément dénommés, suivant la terminologie anglo-saxonne : «*bassins en pull-apart*» («tirés de chaque côté»).

46 Une partie des séismes générés par la convergence se répartit le long de la lithosphère plongeante. Ce panneau sismique est appelé «plan de Wadati-Benioff», du nom des géophysiciens qui l'ont mis en évidence.

47 La correction de la langue française recommande que les formes «subduire/subduit-e» soient utilisées au lieu de «subducter/subducté-e».

croûte plus légère, continentale (cas d'un *arc-cordillère*), ou continentalisée (cas d'un *arc insulaire*, à l'arrière duquel se trouve un *bassin marginal* de nature océanique, appelé également *bassin arrière-arc*). C'est pourquoi on appelle aussi les zones de subduction, *marges actives*, par opposition aux «marges passives», non sismiques, qui résultent de l'éloignement de deux blocs continentaux de part et d'autre d'un «rifting» initial (cas de l'Atlantique). La subduction d'une croûte océanique engendre généralement, en surface, *une ligne de volcans* qui est à l'origine des arcs insulaires et cordillères (cf. aussi II.2.1.3). Ces volcans (caractérisés par des éruptions explosives, donc dangereuses) sont localisés à l'aplomb d'une zone du panneau de subduction («slab») commençant vers une centaine de kilomètres de profondeur, qui est celle à partir de laquelle le slab commence à se déshydrater[48].

La longueur cumulée des zones de subduction est d'environ 55 000 km, un ordre de grandeur comparable à celui des axes d'accrétion océanique (cf. note 10).

Les **zones de subduction actives** sont caractérisées par un **trait vert avec petits triangles pleins** dont la pointe est placée du côté de la plaque chevauchante, et indiquant le sens de la subduction. La convexité des *arcs insulaires* est toujours placée face à la fosse de subduction (p. ex. Petites Antilles dans l'Atlantique, Mariannes dans l'Ouest-Pacifique), mais pour certains d'entre eux, leur profil est pratiquement rectiligne (p. ex. les Tonga-Kermadec dans le SW Pacifique). Du côté concave de l'arc insulaire, le bassin arrière-arc s'est ouvert en se détachant soit d'un continent (cas du Japon partiellement isolé de la marge continentale d'Asie orientale par le petit bassin océanique de la mer du Japon), soit d'un autre arc insulaire devenu un *arc rémanent*, c-à-d. inactif, fossile : p. ex., cas de l'arc actif des Mariannes → bassin (marginal) Ouest-Mariannes → ride (rémanente) Ouest-Mariannes, ou bien arc actif des Tonga → bassin de Lau → ride de Lau).

Les zones de convergence sont généralement marquées dans la morphologie sous-marine par une *fosse de subduction*, dépression étroite et allongée, généralement circonscrite par l'isobathe 5000 ou 6000 m. La plus grande profondeur enregistrée est de 10 920 m dans le Sud de la fosse des Mariannes (voir Feuille 1). Ces fosses ne sont pas toujours visibles, car il arrive qu'elles soient entièrement comblées, sur une partie de leur longueur, par une volumineuse sédimentation d'origine continentale déchargée dans l'océan par les grands fleuves. La tranche supérieure de ces sédiments qui couvrent la plaque descendante, bute contre le bord de la plaque supérieure au lieu de s'engager dans la subduction, et est «écrémée» (échappant ainsi à l'absorption dans le manteau terrestre), en s'empilant en écailles contre l'arc. Il se forme alors un **prisme d'accrétion sédimentaire**, dont le **front de déformation** est indiqué, sur la Carte, par un **symbole** similaire à celui de la subduction, mais **de couleur bleu clair avec des triangles évidés**. Dans l'espace compris entre ce front et l'axe de la fosse de subduction, nous avons laissé apparaître l'âge de la croûte océanique destinée à être subduite, mais masquée par le prisme. Le plus bel exemple de prisme sédimentaire est celui de *la Barbade*, au front de la moitié sud de l'arc des Petites Antilles. Sous l'effet du très puissant alluvionnement en provenance de l'Amazone et de l'Orénoque, son épaisseur maximale atteint environ 20 km sous l'ile éponyme ! Deux autres prismes ont été cartographiés : l'ensemble *méditerranéen* situé au Sud de la Calabre et de la Grèce, et celui du *Makran*. Ce dernier cas est intéressant, car la partie interne du prisme est émergée et forme toute la façade maritime du Baluchistan. C'est pourquoi, dans ce cas, l'axe de la subduction est reporté à terre et indique le contact entre, d'une part le «butoir» (en anglais «backstop») représenté par la lithosphère de la plaque supérieure (Eurasie), et d'autre part celle de la plaque descendante (Arabie).

Rares sont les endroits où l'on peut assister à une **subduction naissante**, représentée par le **figuré** de subduction active (**vert avec triangles évidés**). C'est le cas de la *fosse de Mussau* (vers 149° E, 05° N) où la plaque Caroline commence à s'enfoncer sous la grande plaque Pacifique. Cela se produit aussi au Nord de l'arc des îles de la Petite Sonde pour accommoder le blocage occasionné, au Sud, par la collision avec le bloc continental australien.

On signalera un cas de **subduction fossile** (représentée par un **figuré** similaire, mais **en tireté/point de couleur violette**). Il s'agit de la *fosse* (ou «linéament») *du Vitiaz* dont la profondeur maximale n'est que de 5600 m, et qui s'étire depuis l'archipel des Salomon jusqu'à l'extrémité nord de l'arc des Tonga. En effet, l'arrivée au Miocène du plateau océanique d'Ontong Java, trop «léger» pour être absorbé dans la subduction de la plaque Pacifique qui plongeait alors à cet endroit vers le Sud (sous la plaque Indo-Austalienne), a bloqué tout le système (cf. II.2.2.7). Une réorganisation s'est alors produite, avec basculement de la subduction (en anglais «flip») suivant une polarité inverse (on dit aussi, à «vergence inverse»), sous l'arc des Nouvelles Hébrides.

On aura remarqué que les zones de subduction sont surtout concentrées tout autour du Pacifique et sont la traduction moderne de l'ancienne «*ceinture de feu du Pacifique*». Par ailleurs, il est frappant de constater que, dans cet océan, les arcs insulaires (actifs et rémanents) et leurs bassins marginaux sont exclusivement distribués à l'Ouest, tandis qu'à l'Est, les zones de subduction ne sont surplombées que par des cordillères volcaniques (Andes, chaînes volcaniques d'Amérique Centrale, Rocheuses). En dehors du Pacifique, on ne compte que deux subductions dans l'océan Indien, celles des îles de la Sonde et du Makran, et autant dans l'Atlantique, celles des Petites Antilles et de l'arc de la Scotia (entre Amérique du Sud et Antarctique).

Toutes les *fosses* sous-marines ne pas sont uniquement liées à la subduction. On en trouve notamment le long *de* certaines *failles transformantes* qui hachent l'axe des dorsales d'accrétion océanique, surtout lorsque leur taux d'ouverture est faible. Le record pour ce type de fosse est détenu par la *fosse de la Romanche* dans l'Atlantique Central (centrée sur l'équateur et 18°W, longue de 300 km) qui atteint 7758 m de profondeur.

48 Les volcans de subduction sont situés à une distance verticale du «slab» sous-jacent qui dépasse rarement 150 km.

II.2.2.7- Reliefs sous-marins «anormaux» (monts sous-marins, «plateaux océaniques» , traces de point-chaud)

C'est un vaste ensemble de reliefs de toutes tailles qui affecte tous les océans et auxquels on a attribué, sur la Feuille 2, la même **couleur d'un brun orangé** rappelant un peu, et en plus atténué, celle des trapps sur les continents[49]. En effet, tous ces reliefs résultent d'un magmatisme, généralement puissant, qui est postérieur à l'âge de la croûte océanique «normale» qu'il affecte et qui est issue des axes d'accrétion des dorsales. Si la structure des bassins océaniques n'était régie que par les processus de la «tectonique des plaques», on n'y verrait que des dorsales d'accrétion, des failles transformantes, des plaines abyssales et des fosses de subduction et leurs arcs insulaires associés[50]. Ces reliefs, donc tous d'origine volcanique, proviennent de l'activité d'un point-chaud (quelle que soit la signification qu'on lui attribue, cf. II.3) relativement fixe, à certaines exceptions près. On distingue :

- des *monts sous-marins* («seamounts»), reliefs individuali sés, de taille relativement réduite, pouvant être nappés de sédiments, et dont le sommet est parfois plat (cas des «guyots»), car provenant de l'érosion d'un volcan subaérien, qui s'enfonce progressivement sous la mer, sous l'effet de la subsidence thermique.
- des *plateaux océaniques* (cf. aussi II.1.3).
- des *traces de point-chaud*, naguère (et encore parfois) appelées «*rides asismiques*» parce que ce sont des «dorsales» qui ne montrent aucune sismicité, contrairement aux dorsales médio-océaniques placées, elles, aux frontières de plaques.

Un **plateau océanique** est généralement édifié en un temps relativement bref à l'échelle des temps géologiques, lors d'une phase d'intense activité du point-chaud. **L'âge moyen** de ce dernier est indiqué par un **nombre rouge** suivi de «**Ma**» (p. ex. «123 Ma» pour celui du plateau de Manihiki, au NE des Samoa), ou de 2 nombres séparés par **&** quand on suppose que l'édification s'est effectuée en 2 pulsations majeures. Si l'âge est imprécis à l'intérieur d'un intervalle, c'est la fourchette qui est donnée, les 2 nombres étant reliés par un **trait d'union**. L'âge (parfois assez approximatif) n'a été donné que pour 10 plateaux océaniques : dans l'océan Indien , la *Maud Rise* (73 Ma; 0°E/W, 65,5° S), le plateau des *Kerguelen* (119 Ma & 100 Ma), le plateau de *Broken Ridge* (95 Ma; 95°E, 30°S); dans le Pacifique, la *Shatsky Rise* (147 Ma; 160°E, 35°N), la *Hess Rise* (99 Ma; 180° E/W, 35°N), le plateau de *Manihiki* (123 Ma; 165°W, 10°S), le plateau d'*Ontong Java* (121 Ma & 90 Ma), le plateau d'*Hikurangi* (120-100 Ma, immédiatement à l'Est de la Nouvelle-Zélande et plaqué contre sa marge continentale); dans l'océan Atlantique, le plateau *Caraïbe* (90 Ma & 76 Ma), la *Sierra Leone Rise* (73 Ma; 20°W, 05°N).

Le plateau océanique *d'Ontong Java*, qui tire son nom d'un atoll situé au Nord de l'archipel des Salomon, est le plus remarquable de tous. C'est le plus grand, avec une superficie estimée à quelque 2 millions de km^2 et un volume d'environ 40-45 millions de km^3, avec une croûte anormale épaisse pouvant atteindre plus de 30 km. Il s'est formé à la mi-temps du Crétacé, vers 122 Ma, et probablement aussi au cours d'une deuxième pulsation magmatique autour de 90 Ma. Certains auteurs pensent que ce plateau est né de la «tête» (panache) du point-chaud de *Louisville* (HE sur cette feuille) qui se trouve dans le Sud du Pacifique (140° W, 50°S)[51]. On a vu (II.2.2.6) qu'il avait atteint l'ancienne zone de subuction du Vitiaz vers 20 Ma, puis était entré en collision avec l'arc insulaire des Salomon il y a environ 4 Ma, en bloquant définitivement cette subduction en raison de sa densité plus faible que celle d'une croûte océanique normale (effet de bouée).

Dans la théorie classique, un point-chaud (en anglais, «hotspot») est situé plus ou moins profondément sous une plaque lithosphérique qui se déplace au-dessus de lui, à la vitesse et selon le sens contrôlés par l'axe d'accrétion d'où est issue la plaque. Au début de son existence, le point-chaud émet un large panache qui, en atteignant la lithosphère, produit un volcanisme de surface, volumineux et relativement fluide, et dans un laps de temps géologiquement court. Il se forme alors de vastes épanchements géographiquement circonscrits : trapps, à terre, et des plateaux océaniques[52], en mer. Lorsque le panache se dissipe, la «queue» (ou «tige») du point-chaud continue d'émettre, mais avec un débit plus réduit, généralement pendant une durée beaucoup plus longue qui est enregistrée par la progression de la plaque sus-jacente, sous la forme d'une chaîne de volcans, d'abord actifs, puis qui éteignent et s'enfoncent sous la mer en s'éloignant du point chaud nourricier. Les maillons de cette chaîne sont donc d'autant plus vieux que l'on s'éloigne du point d'origine.

L'ensemble forme une **«trace de point-chaud»** (en anglais : «hotspot track ou hotspot trail»). L'exemple bien connu est celui d'*Hawaï* (symbole HC sur la Feuille 2) où l'activité volcanique est aujourd'hui localisée sous Big Island (volcans boucliers du Mauna Loa et du Kilauea, et l'appareil sous-marin du Loihi[53], plus récent – petit triangle bleu reporté sur la Feuille 1). La partie la plus ancienne encore visible de cette trace est le mont sous-marin Meiji (daté à 85 Ma), situé devant la fosse de subduction des Kouriles, prête à l'engloutir. On notera, à mi-course (vers 40 Ma), le changement d'orientation de la chaîne qui passe d'une direction SE-NW, à une orientation S-N, et qui indique qu'il y a eu une réorientation de la plaque Pacifique à cette époque.

Pour un certain nombre de traces de point-chaud, nous avons indiqué, outre celui d'Hawaï qui vient d'être mentionné, **l'âge de différents jalons** avec un **nombre rouge sans** ajouter «**Ma**». Ce sont les traces de celui :

49 Les contours violets dessinés à l'intérieur de ces structures désignent des reliefs de deuxième ordre.
50 Voir les réserves à apporter à cette assertion en II.3.
51 La formation du plateau d'Ontong Java par un point-chaud a été récemment mise en question avec l'hypothèse d'un magmatisme cataclysmique déclenché par l'impact d'une météorite géante (cf. Ingle S. & Coffin M., 2004, *E.P.S.L.*, 218 :123-134).
52 Pour les temps présents, on ne connaît pas de cas de trapps ni de plateaux océaniques en voie de formation.
53 Le Loihi, situé à 34 km au SE de Big Island, culmine à –1000 m (au «Pelé Pit»); c'est l'expression la plus récente du point-chaud.

- de *La Réunion* (HF) qui relie cette île aux trapps du *Deccan* en passant par l'île Maurice, le banc de Nazareth, le banc des Chagos, la ride des Maldives-Laquedives. Mais l'ouverture postérieure de la dorsale d'accrétion océanique de Carlsberg a coupé en deux et décalé l'alignement initial qui comprenait en outre les bancs de Saya de Malha et des Seychelles (pour ce dernier point, cf. aussi II.1.3).
- des *Kerguelen* (Hi) probablement à l'origine du Broken Ridge plateau et de la Ninetyeast Ridge[54] (transposée en français en «ride Nonantest» par J. R. Vanney) et peut-être des trapps de *Rajmahal* et de *Sylhet*.
- de *Louisville* (HE) dont le tracé (ride de Louisville) aboutit à la zone de subduction des Tonga-Kermadec (et qui a peut-être créé le plateau océanique d'Ontong Java, comme on l'a vu plus haut[55] .
- de *Tristan da Cunha* (HG), à l'origine de la ride du Rio Grande, à l'Ouest, et de celle de Walvis, à l'Est, qui se raccordent respectivement aux trapps du Parana et d'Etendeka dont on a vu (cf. II.1.3) qu'ils formaient un seul ensemble il y a 133 Ma, avant l'ouverture de l'Atlantique Sud.
- de l'*île de Pâques* (HB), qui a donné naissance à la ride de Sala y Gomez qui se poursuit par celle de Nazca dont le bout s'enfonce dans la subduction de la fosse du Pérou.

II.2.2.8- Limite diffuse de plaques

Un figuré de **hachures grises** couvre les secteurs océaniques où la frontière transformante (coulissante) entre deux plaques est mal définie, diffuse, sur une bande de largeur variable, p. ex. entre les plaques Amérique du Nord et Amérique du Sud, ou sur une partie de la faille transformante située à l'Est des Açores, qui sépare la plaque Eurasie de la plaque Afrique.

Mais le secteur le plus largement représenté se trouve dans le centre de l'océan Indien et relie un tronçon de la dorsale (d'accrétion) Centrale Indienne à la zone de subduction de la Sonde, du Nord de Sumatra au milieu de Java, c'est à dire traversant toute la largeur de la plaque Indo-Australienne. Il ne s'agit pas encore d'une vraie frontière séparant une plaque Inde d'une plaque Australie, mais d'un secteur où le substratum basaltique est déformé sous l'effet de contraintes compressives (en réponse à la collision continentale de l'Inde sous le Tibet,) et qui connaît une sismicité également diffuse.

II.2.2.9- Volcanisme sous-marin lié à l'ouverture de l'Atlantique Nord

Un **hachuré rouge** indique la présence de **SDRs** (**S**eaward **D**ipping **R**eflector **s**equences) ou séquences de réflecteurs pentés vers l'océan (repérés par la technique géophysique de sismique-réflexion continue), ou de **basaltes sous-marins** massifs, affleurants ou enfouis, témoignant tous d'une intense activité volcanique liée à l'ouverture de l'Atlantique Nord au Paléogène (cf. II.2.2.4) et au fonctionnement du puissant **point-chaud** *de l'Islande* (HD). Ces éléments affectent les marges continentales conjuguées (et parfois un peu au-delà pour les SDRs) du Groenland, d'une part, et des îles Britanniques et de la Norvège, d'autre part. Cette activité éruptive est connue à terre (volcanisme «V 1» de la légende), aussi bien au Groenland qu'aux îles Féroé et en Irlande (Chaussée des Géants). Les SDRs correspondraient à une série de strates où alternent coulées volcaniques (laves et dépôts pyroclastiques) et dépôts sédimentaires non volcaniques.

II.2.2.10- SDRs liés à l'ouverture de l'Atlantique Sud

Dans l'Atlantique Sud, l'exploration pétrolière a, plus récemment, mis en évidence des **SDRs** (**hachuré bleu)** sur les marges continentales conjuguées d'Argentine et de Namibie-Afrique du Sud. La présence de ces réflecteurs est à mettre en rapport avec l'ouverture de l'Atlantique Sud et la présence du point-chaud de *Tristan da Cunha* (HG).
L'exemple de ces deux bassins atlantiques montre que les marges continentales passives (c. à d. issues d'un rift continental initial et ne correspondant pas à une limite de plaque) ne sont pas uniquement «non volcaniques», comme on le pensait avant la découverte des SDRs. Il est même possible que la présence d'un point-chaud soit déterminante dans le rifting d'un bloc continental et l'ouverture subséquente d'un océan.

II.3 – POINTS-CHAUDS

La théorie du point-chaud (cf. II.1.3; II.2.2.7) est due au géophysicien canadien John Tuzo Wilson qui l'a formulée en 1963 (deux ans avant qu'il n'élabore celle des failles transformantes) en prenant pour modèle Hawaï. Cette théorie séduisante a eu un énorme succès parce qu'elle a fourni une explication cohérente à la distribution d'un volcanisme spécifique, exprimé généralement hors des limites de plaques (d'où le nom de *volcanisme intraplaque*) et particulièrement dans le domaine océanique. La liste des points-chauds comprenait à l'origine une vingtaine de cas, mais leur nombre a démesurément enflé jusqu'à près de 130 unités, voire beaucoup plus (près de 5200 pour Malamud et Turcotte[56] en 1999; mais à ce niveau-là, se pose la question du sens que l'on accorde au terme «point-chaud»). Aujourd'hui, on est revenu à un nombre plus modeste, entre 40 et 50. Mais tous ne correspondent pas au modèle d'origine dont les critères de base (sans aborder le domaine géochimique) sont : l'origine profonde d'un panache mantellique, et un fonctionnement de longue durée (plusieurs dizaines de millions d'années) qui détermine la progression d'une trace volcanique en surface. Dans ces cas non conformes au modèle, on parle alors de points-chauds peu profonds, ou «faibles» (weak), ou de «lignes chaudes» (hotlines), etc. Ce dernier cas est bien illustré par

54 Cette ride tire son nom de sa position géographique, car située le long du méridien 90° E.
55 Dans ce cas, le segment manquant aurait été progressivement absorbé par cette subduction; le mouvement de la plaque Pacifique étant dirigé vers l'Ouest.
56 Cf. D. Anderson et J. Natland, (p.134) dans l'ouvrage cité dans la note suivante.

l'alignement volcanique NE-SW du Cameroun où l'âge du volcanisme n'est pas distribué suivant une progression régulière, mais sur un mode assez aléatoire, avec un volcan côtier actif, le mont Cameroun (+ 4095 m) situé à peu près à mi-chemin entre les deux extrémités de la ligne situées, l'une au Nord du Cameroun, l'autre au-delà de la petite île de Pagalu (ex-Annobon). La contestation du concept de point-chaud est encore plus radicale depuis le début des années 2000, où certains chercheurs (les «anti-plumers», en anglais; voir p. ex. les travaux récents de Don L. Anderson) nient l'existence d'un grand nombre de «panaches» («plumes» en anglais) et proposent d'expliquer l'origine des *LIP* (Grandes Provinces Magmatiques, cf. II.1.3.) essentiellement par des déformations liées à la seule tectonique des plaques (au sens strict de ce concept), provoquant des déchirures de la lithosphère (contraintes de cisaillement), favorisées par des lignes de faiblesse préexistantes comme les zones de fracture[57]. Ce cas semble s'appliquer au Pacifique Central –voir notamment les travaux de l'IRD/IPGP, (Valérie Clouard et Alain Bonneville), et de l'USGS (Marcia McNutt et coll.) avec les points-chauds du linéament Samoa (H27)-Rarotonga (H25)-Arago (H1)-Mcdonald (H21)-Foundation (H15), et du segment Tahiti (H30)-Pitcairn (H24).

Cette très active controverse est hébergée par le très intéressant site web : < www.mantleplumes.org >.
Quoi qu'il en soit, nous avons pensé qu'il pouvait être utile, à titre informatif, de reporter sur la Feuille 2 **la position** exacte ou supposée de **45 points-chauds** (leur liste est donnée par l'**encadré** placé dans la marge inférieure de la Carte**).**

Nous les avons répertoriés en 4 catégories, en nous inspirant notamment de la classification de Vincent Courtillot et collaborateurs, (2003) :

1/ les points-chauds «primaires», supposés correspondre à un panache puissant, profond, de longue durée, notés HA à HG (**grand cercle rouge continu**);
2/ ceux qui pourraient être considérés comme primaires, notés Hh et Hi (**grand cercle rouge en pointillés**);
3/ ceux qui sont moins caractéristiques, problématiques, ou contestés, notés H1 à H34 (**petit cercle rouge)**;
4/ ceux qui seraient éteints depuis beaucoup plus de 1 Ma, mais qui auraient laissé des traces dans la morphologie sous-marine (**petit cercle bleu**) : celui du Great Meteor Bank (eH1) au Sud des Açores qui aurait édifié l'alignement des monts sous-marins de Nouvelle-Angleterre, et celui de Ste Hélène (eH2).

Les points-chauds des 3 premières catégories sont généralement considérés comme «vivants», avec du volcanisme actif, ou relativement récent (comme au Hoggar), en tête de ligne. La majorité des points chauds sont situés en zone océanique. Seuls 6 se trouvent à terre : Afar (HA), Cameroun (H17), Darfour/Djebel Marra (H13), Hoggar (H17), Tibesti (H32), Yellowstone (H34).

En guise de conclusion …

…on signalera que la Feuille 2 peut être utilisée comme base pour tracer de manière explicite les contours des différentes plaques, sous-plaques et microplaques lithosphériques qui organisent, en la découpant, la surface actuelle de notre planète, résultante d'un affrontement ininterrompu entre les dynamiques de création et les facteurs de destruction. Un complément utile à la lecture de cette Carte à 1/50 000 000, pourra être fourni par deux autres documents de la CCGM de même échelle :

- *La tectonique des plaques depuis l'espace* (2006, N. Chamot-Rooke & A. Rabaute) pour une représentation des mouvements actuels des plaques lithosphériques, les unes par rapport aux autres;
- La *Carte sismotectonique du Monde* (2002, A. Haghipour et collaborateurs) pour la distribution des séismes, notamment aux frontières de plaques, où sont distinguées plusieurs catégories de magnitude et de profondeur des foyers des tremblements de terre.

POUR EN SAVOIR PLUS

Pour les lecteurs francophones qui souhaiteraient aller plus avant dans la compréhension d'une grande partie des thèmes qui n'ont été qu'effleurés au fil de ces Notes, nous suggérons une courte liste, forcément non exhaustive, d'ouvrages destinés aux étudiants de licence, mais qui peuvent aussi s'adresser à un plus large public intéressé par l'explication des processus géologiques qui façonnent la surface de notre planète :

- *La Terre, une planète singulière* (2003) par R. Trompette, Éditions Belin
- *Introduction à la géologie; La dynamique de la lithosphère* (2003) par G. Boillot, Ph. Huchon & Y. Lagabrielle, Éditions Dunod
- *La subduction océanique* (1999) par S. Lallemand, Éditions Gordon & Breach Science Publishers
- *La tectonique des plaques* (2002) par M. Westphal, H. Whitechurch & M. Munschy, Éditions Gordon & Breach Science Publishers & Société Géologique de France
- *La croûte océanique, pétrologie et dynamique endogène* (2008) par Th. Juteau & R. Maury, Éditions Vuibert & Société Géologique de France
- *Les Roches, mémoire du temps* (2008) par G. Mascle, «collection Grenoble Sciences», Éditions EDP Sciences.
- *Dictionnaire de la tectonique des plaques et de la géodynamique* (2000) par J. M. Vila, Éditions Gordon & Breach Science Publishers & Société Géologique de France

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57 D. Anderson et K. Schramm utilisent dans leur article «The complete hotspot catalogue» *in* : *Plates Plumes & Paradigms* (Geol. Soc. Amer., Special Paper no. 558, 2005, p. 19-29), avec une certaine dose d'humour, les néologismes «Notspots» et «Crackspots», pour désigner ces points-chauds «déchus».

COMPTES CCGM

2007 & 2008

COMMISSION DE LA CARTE GEOLOGIQUE DU MONDE
COMMISSION FOR THE GEOLOGICAL MAP OF THE WORLD

YEAR 2007 FINANCIAL STATEMENT
(YEAR ENDING DECEMBER 31, 2007)

	ACCOUNT IN EUROS	ACCOUNT IN USD		TOTAL IN EUROS
		USD	Equivalent in EUROS	
OPENING (01.01.07)(1)	**€ 83 235,13**	**$257 692,36**	**€ 195 846,19**	**€ 279 081,32**
INCOME 2007				
Membership fees(2)	59 693,20			59 693,20
Corporate subsidies	1 200,00			1 200,00
BRGM subsidy	15 200,00			15 200,00
IUGS subsidy		*4 000,00*	2 932,00	2 932,00
UNESCO support - map preparation	6 244,00			6 244,00
Sponsoring for map digitizing and printing(3)	22 950,00			22 950,00
Publication sales	52 820,86			52 820,86
Financial income and saving account interest(4)	3 384,56			3 384,56
USD account interest		*1 434,93*	1 051,80	1 051,80
Various refunds	6 493,17			6 493,17
TOTAL	**€ 167 985,79**	***$5 434,93***	**€ 3 983,80**	**171 969,59**
2008 incomes received in advance(9)	-€ 10 279,00			-10 279,00
EXPENSES 2007				
Salaries(5) and social contributions	48 726,72			48 726,72
Chartered accountant	2 000,00			2 000,00
Training courses (Adobe Illustrator)	1 255,80			1 255,80
Projects support and map preparation(6)	16 045,85	*2 000,00*	1 466,00	17 511,85
Participation to international and national exhibitions & events	2 862,88	*1 050,00*	769,65	3 632,53
Meetings, missions(7)	2 140,95			2 140,95
Maps & CD printing	5 924,44			5 924,44
Marketing costs	6 937,32			6 937,32
Purchase of maps & documents	1 023,98			1 023,98
Office rent, insurance, taxes, cleaning	19 634,43			19 634,43
Postage, phone, fax, internet	9 875,02			9 875,02
Bureautics(8), photocopier location	4 957,18			4 957,18
Office supplies & maintenance	3 388,35			3 388,35
Banking fees	1 009,07	*99,49*	72,93	1 082,00
Taxes on financial revenues in 2006	1 325,00			1 325,00
TOTAL	**€ 127 106,99**	***$3 149,49***	**€ 2 308,58**	**€ 129 415,57**
2008 expenses paid in advance	-€ 1 027,04			*-€ 1 027,04*
Change in inventory	€ 16 073,81			*€ 16 073,81*
Balance 2007(9)	**€ 41 905,84**	***$2 285,44***	**€ 1 675,23**	***€ 17 228,26***
Latent currency exchange loss				*€ 19 176,65*
CLOSING (31.12.07)(10)	**€ 124 113,93**	***$259 977,80***	**€ 178 344,77**	***€ 302 458,70***

1) The amounts of the opening are calculated at the rate of 0,76 x 1 USD effective on December 31, 2006
(2) The average exchange rate for 2007 is calculated at 0,733 x 1 USD (UN operational rates of exchange)
(3) Subvention from TOTAL & BRGM
(4) Only interest in Euros are accounted. In 2007, the potential interest of securities for 219 800 USD amounted to 8 380 USD
(5) Assistant-secretary on a full-time basis and employer's social contributions
(6) Financial support to maps preparation and related meetings
(7) Includes missions of Secretariat General board & public relations expenses
(8) Soft and hardware acquisitions, maintenance and supplies for computer & photocopier
(9) Includes a provision of 10 279 Euros for map printing in 2008 received from TOTAL
(10) Closing calculated at 0,686 x 1 USD, exchange rate effective on December 31, 2007

COMMISSION DE LA CARTE GEOLOGIQUE DU MONDE
COMMISSION FOR THE GEOLOGICAL MAP OF THE WORLD

YEAR 2008 FINANCIAL STATEMENT
(YEAR ENDING DECEMBER 31, 2008)

Consolidated in Euros

OPENING (01/01/08)			**396 860,74 €***
INCOME 2008			
Membership fees	57 421,52 €		
Subsidies (UNESCO, BRGM, IUGS, TOTAL)	51 593,02 €		
Mapping sponsoring	14 950,00 €		
Publication sales	45 000,46 €		
TOTAL I		168 965,00 €	
Financial income and account interest	23 254,79 €		
TOTAL II		23 254,79 €	
TOTAL I + II		**192 219,79 €**	
EXPENSES 2008			
2008 expenses paid in advance			**-10 279,00 €**
Map production	44 079,22 €		
Purchase of Maps and Documents	5 023,31 €		
Sales costs - Marketing	5 504,66 €		
Participation to international and national exhibitions & events	23 586,14 €		
Meetings, missions	2 829,90 €		
Postage, phone, fax, internet	7 525,51 €		
Bureautics	5 634,31 €		
Office supplies & maintenance	23 824,76 €		
Financial taxes	745,00 €		
Banking fees	1 764,29 €		
Salaries and social contributions	57 804,00 €		
Stock variation	-9 723,68 €		
TOTAL III		168 597,42 €	
Change loss	1 239,79 €		
TOTAL IV		1 239,79 €	
TOTAL III + IV		**169 837,21 €**	
BALANCE 2008 (TOTAL I + III - TOTAL III + IV)		**22 382,58 €**	**22 382,58 €**
2009 expenses paid in advance	17 000,00 €		**17 000,00 €**
CLOSING (31/12/08)			**425 964,32 €**

* Corresponds to: **302 458,70** Closing 2007
93 125,00 Stock estimate
1 027,04 Expenses paid in advance in 2007
250,00 Salary advance

ANNEX

Resumes of new CGMW Bureau Members

Curricula vitae des nouveaux Membres du Bureau

MANUEL F. PUBELLIER
Geologist, PhD

Expertise: Regional synthesis of geological/geophysical data, and cartography of deformed tectonic belts and basins, particularly in convergent and strike-slip settings. Tectonic & magmatic environment of ores and oil environments.

Areas of investigation: oblique convergent margins, SE Asia (Philippines, Indonesia, New Guinea, Burma) and Caribbean. Deformed cratonic areas (China)

Tools: Structural geology in tropical and subtropical environment, tectonic and fault-slip analyses, satellite and aerial imagery including SAR and multispectral, cartography and GIS

Project Manager of the following recent projects :
- Tectonic setting of Porphyry-Copper deposits (NBM, BRGM/GENCOR/MINSAKO)
- Deep offshore Tectonic synthesis (CONOCO, EXXON, UNOCAL, TOTAL-FINA-ELF),
- Strain in Borneo (UNOCAL), and Sunda (TOTAL)
- Cartography and GIS (UNESCO-CGMW)
- Mapping & Remote Sensing (TOTAL, NAPOCOR, FUGRO-GEOTEAM)

Publications : **93 publications, 117 abstracts, 9 geological maps**

Languages
French, English and Spanish fluent.
German, Chinese (cantonese), Indonesian and Haitian creole understood

Present Position :
Researcher at CNRS (French National Council for Scientific Research)
Secretary General elect of the Commission for the Geological Map of the World (CGMW/CCGM)

Contributions to CGMW
Short contrat, Maps archiving at CGMW **1983**
Member of **DIMAS**, **2005-2007**
Participation to 5 CGMW maps
Editor Geological Map of Asia, **IGMA5000 2005-2008**
Author Structural Map of Eastern Eurasia, **2005-2008**

Teaching experience :
Lecturer at Universities : Port au Prince (Haïti 1984-1986), Univ Paris 6, P&M. Curie (1990-1996), ENS Paris (1997-2008), IFP School (1995-2007), Chinese Acad Sci. Beijing (2005), Hong Kong University (2003, 2005-2007), University Petronas Malaysia (2006-2008)
Supervision of 12 PhD students from 1995 to 2008

Publication or participation at published geological maps

1987 Boisson D. **Pubellier M**. Carte Géologique D'Haiti. Echelle 1/250.000, Feuille NE.(Cap Haïtien), ***IMAGEO-CNRS***,

1987 Boisson D. **Pubellier M**. Carte Géologique D'Haiti. Echelle 1/250.000, Feuille NO.(Môle Saint Nicolas), ***IMAGEO-CNRS*** , Univ.P.& M. Curie (France)

1993 **Pubellier M.**, Quebral R., Deffontaines B., Rangin C. Neotectonic Map of Mindanao 1:800,000 ((E 121°00'--E 128°00'/N 10°00'--N 5°00') with 23-pages explanatory note. Printed and distributed by ***Asia Geodyn. Co.***, , Philippines.

2001 Haghipour A, et al. seismotectonic map of the world, Carte sismotectonique du monde, scale 1: 25 000 000, 1st edition, 2001, published by ***CGMW and UNESCO***

2002 **Pubellier, M.**, Rangin, C., Le Pichon X., Ego, F., Nguyen H., Nielsen, C., Rabaute, A., Tsang Hin Sun, D., Bousquet, R., Deep Offshore Tectonics of South East Asia (DOTSEA); a synthesis of deep marine data in SouthEast Asia. Exxon-Conoco-Unocal-ENS Consortium Maps(restricted publication), 27 maps.

2004 Segoufin, J., M. Munschy, M., Bouysse P., Mendel, V., Grikurov, G., & G. Leitchenkov, G., Subrahmayan C, Chand, S., **M. Pubellier**, M. Structural map of the Indian Ocean, Carte structurale de l'Océan Indien, scale 1: 20 000 000, 1st edition, 2004, published by ***CGMW and UNESCO***

2004 **Asch C. & al. (…M. Pubellier), 2004**. IGME 5000 : International Geological Map of Europe and Adjacent Areas, *IGME – Commission for the Geological Map of the World (CGMW)* , 2 sheets : 167x127 cm, 1:5.000.000 scale.

2005 **Pubellier, M.**, Rangin, Ego et al. 2005, Atlas of the margins of SE Asia. ***Geol Soc. France / Amer. Assoc. Petrol. Geologists***, N°176, 6 maps, 4 chap., 1CDRom. ISBN 2-85363-090-0, ISSN 0249-7549

2007 **PUBELLIER, M.**, CHAN, L.S., ET AL., 2007, MORPHO-TECTONIC MAP OF CENOZOIC STRUCTURES OF THE SOUTH CHINA / NORTHERN VIETNAM COASTAL REGION. MAP WITH EXPLANATORY NOTES AND CDROM, ***OUTPUT-EXPRESS PRINT OFF***. HONG KONG, ISBN 978-988-98896-4-7, 16P.

2008 **PUBELLIER**, M. STRUCTURAL MAP OF EASTERN EURASIA;, SCALE 1:12.500.000, 1ST EDITION, 2008, PUBLISHED BY ***CGMW*** *(IN PRESS)*

2009 **BOUYSSE P.…**, M. PUBELLIER ET AL., GEOLOGICAL MAP OF THE WORLD, SCALE 1:25 000 000, 2NDED, 2008, PUBLISHED BY ***CGMW*** *(IN PRESS)*

Yves Lagabrielle

First class Research Director at the CNRS (French National Council for Scientific Research)
French, born in Nov. 30th 1955
Affiliation : Géosciences Montpellier, Equipe Lithosphère
UMR CNRS-UM2 5243, CC. 60, place E. Bataillon, 34095 Montpellier cedex 5
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yves.lagabrielle@gm.univ-montp2.fr
http://www.gm.univ-montp2.fr.

Education

Ecole Normale Supérieure of Saint Cloud (1976), Agrégé de Sciences Naturelles (1979)
Docteur 3ème Cycle (Ph.D. 1982). Docteur d'Etat (1987).

Professional experience

Chargé de Recherche CNRS, GIS Océanologie-Géodynamique Brest, France 1982-1991
Directeur de Recherche CNRS, UMR Domaines Océaniques Brest France, 1991-1999
Directeur de Recherche, Centre Géologie –Géophysique IRD, Nouméa, New Caledonia
Directeur de Recherche CNRS, UMR Domaines Océaniques Brest France, 2002-2003
Directeur de Recherche, UMR DL, Géosciences Montpellier, 2004-20..

Research interests

Global geodynamics onshore and offshore. Mid-oceanic ridges, mantle exhumation processes during lithosphere stretching. Mountain buildings in converging settings.

- Twenty years investigations on the processes of lithosphere accretion at fast- to slow-spreading ridges and in back-arc environments (more than 10 marine campaigns, including 10 dives with submersibles Cyana and Nautile).
- Ten years involved within international research programs on the geodynamics of the Southwest Pacific region (North Fiji, Lau basins), mostly focusing on the active spreading axis system.
- Two years investigations on active tectonics in the Southwest Pacific region (Vanuatu arc)
- Fifteen years involved in field and marine research programs relative to the processes of active ridge subduction beneath southern South America (Chile Triple Junction, Tectonic evolution of Patagonia).
- Ten years research on the evolution of the internal ophiolite-bearing units of the western Alps and the problem of mantle exhumation in the Pyrenean belt.

Teaching experience

- Head of Master 2 Géodynamique at Université Montpellier 2.
- Courses : Evolution of the Oceanic Lithosphere, Accretion processes in the SW Pacific, Tectonic evolution of the Andes, Tectonic evolution of the Alps,...
- Various talks and meetings for teachers in various Regional Boards of Education in France : from the Scientific labs to the students in Earth Science domains since 1990.

Professional affiliations and positions

- Elected member of various National Commities since 1998 : CNU, IRD,
- Elected member of CNRS Comité National section 18 - Terre et planètes telluriques : structure, histoire, modèles.
- Member of various scientific committees and programs in France.
- Editor in chief of the Société Géologique de France

Publications

Number of articles published in peers reviews including Nature, Geology, JGR, EPSL, Tectonophysics, Terra Nova, BSGF, etc…: **103** in 2008

Citation Index (after ISI Web of Science, General Search in 2006) : 1194
Hn Index = 19

Books for education in Earth Sciences

Elements de Géologie : Pomerol-Lagabrielle-Renard (Dunod). Total sold : 7500 pieces
Introduction à la Géologie : Boillot-Huchon-Lagabrielle (Dunod). Total sold : 1000 pieces
Le visage sous-marin de la Terre : Lagabrielle-Leroy et coll. (CCGM). Total sold : 1200 pieces

July 2008

Prof. Dr.. Mioara Mandea
Helmholtz-Zentrum Potsdam
Deutsches GeoForschungsZentrum GFZ

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E-Mail: mioara@gfz-potsdam.de

MAIN SCIENTIFIC INTERESTS:

OBSERVATION OF THE EARTH'S MAGNETIC FIELD, FROM MODERN OBSERVATORY / SATELLITE DATA TO HISTORICAL ARCHIVES:

Absolute measurements and data processing in magnetic observatories and repeat station networks.
Data quality control for observatories participating in INTERMAGNET program.
Installing new observatories or modernizing existing ones.
Database for monthly means for worldwide observatories.
Satellite data quality.
Historical data (around the world).

DESCRIPTION OF TEMPORAL AND SPATIAL CHANGES OF THE GEOMAGNETIC FIELD:

Description of temporal and spatial changes of the geomagnetic field: o Modeling the core field and its secular variation (IGRF, OIFM, POMME, CHAOS).Studies of geomagnetic jerks.

World Digital Magnetic Anomaly Map (IAGA / UNESCO).

ADAPTING OF NEW MATHEMATICAL TOOLS FOR GEOMAGNETIC DATA ANALYSIS:

Wavelets Analysis (temporal, on the sphere).
Multi-taper method.

STUDIES ON THE EARTH'S DEEP INTERIOR:

Computation of the fluid motions at the core-mantle boundary.
Lower mantle properties.

STUDIES OF THE MARTIAN MAGNETIC FIELD

STUDIES OF THE MERCURY MAGNETIC FIELD

EDUCATION

2001: HDR, "Habilitation à diriger les recherches", Physics of the Earth (University Paris VII).
1996: PhD, Internal Geophysics (Institut de Physique du Globe de Paris).
1993: PhD, Geophysics and Geophysical Prospecting (Bucharest University).
1982: Engineering in Geology and Geophysics (Bucharest University).

PROFESSIONAL EXPERIENCE

Since 2005 Head of Section 2.3 at GFZ Potsdam.
1994 - 2004 Physicist, Head of French National Magnetic Observatory.
1991 - 1993 Various fellowships at Institute de Physique du Globe, Paris.
1984 - 1994 Researcher, Geomagnetism department, Institute of Geology and Geophysics, Bucharest.
1982 - 1984 Engineer, Gravimetry section, Geological and Geophysical Survey, Bucharest.

AWARDS

2000 **Botezatu**, Romaniae Scientiarum Societas.
1998 **Hepites**, Romanian Academy.
1997 **Van Straelen**, French Geological Society.

PROJECTS

Geotechnologien (D): Developing tools to improve CHAMP data processing and geomagnetic field descriptions.
Swarm (ESA/EADS): End-to-end simulatior and participation in definition of this multi-satellite mission.
Magflotom (EU): Ocean and core flows from the high-resolution magnetic data.
Inkaba (D/SA): Studies of the anomalous behavior of the magnetic field over Southern African Continent.

PUBLICATIONS (SELECTION)

2008

- Lesur, V.; Wardinski, I.; Mandea, M. (2008): GRIMM: the GFZ Reference Internal Magnetic Model based on vector satellite and observatory data, Geophysical Journal International, 173, 2, 382-394.
- Olsen, N.; Mandea, M. (2008): Rapidly changing flows in the Earth's core, Nature geoscience, 1, 390-394.
- Wardinski, I.; Holme, R.; Asari, S.; Mandea, M. (2008): The 2003 geomagnetic jerk and its relation to the core surface flows, Earth and Planetary Science Letters, 267, 3-4, 468-481.

2007

- Auster, H. U.; Mandea, M.; Hemshorn, A.; Pulz, E.; Korte, M. (2007): Automation of absolute measurements of the geomagnetic field, Earth Planets and Space, 59, 9, 1007-1014.
- Balasis, G.; Mandea, M. (2007): Can electromagnetic disturbances related to the recent great earthquakes be detected by satellite magnetometers?, Tectonophysics, 431, 173-195.
- Chambodut, A.; Eymin, C.; Mandea, M. (2007): Geomagnetic jerks from the Earth's surface to the top of the core, Earth Planets and Space, 59, 7, 675-684.
- | Wicht, J.; Mandea, M.; Takahashi, F.; Christensen, U. R.; Matsushima, M.; Langlais, B. (2007): The origin of Mercury's internal magnetic field, Space Science Reviews, 132, 2-4, 261-290.

| 2006

- Books

2007

- Korhonen, J. V.; Faihead, J. D.; Hamoudi, M.; Lesur, V.; Mandea, M.; Maus, S.; Purucker, M.; Ravat, D.; Sazonova, T.; Thebault, E. (2007): Magnetic anomaly map of the world = Carte des anomalies magnétiques du monde, CCGM - CGMW (Commission de la Carte Géologique du Monde).
- | Mandea, M.; Thébault, E. (2007): The changing faces of the earth's magnetic field : a glance at the magnetic lithospheric field, from local and regional scales to a planetary view, Commission for the Geological Map of the World, 49 + 1 CD-ROM.

- Mandea, M.; Thébault, E. (2007): The changing faces of the Earth's magnetic field : a glance at the magnetic lithospheric field, from local and regional scales to a planetary view, Commission for the Geological Map of the World (CCGM/UNESCO), 49.

LECTURES (SELECTION)

2008

- Hemshorn, A.; Pulz, E.; Mandea, M.; Korte, M.; Auster, U. (2008): GAUSS - Improvements to the Geomagentic Automated SyStem, 13th IAGA Workshop on Geomagnetic Observatory Instruments, Data Acquisition and Processing (Golden and Boulder, Colorado 2008). |
- Korte, M.; Mandea, M.; Kotzé, P. (2008): Utility and accuracy of geomagnetic repeat station surveys, 13th IAGA Workshop on Geomagnetic Observatory Instruments, Data Acquisition and Processing (Golden and Boulder, Colorado 2008).
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PROFESSIONAL EXPERIENCE

2006-2008	General Director of National Geosciences Database of Iran
2003-2005	Deputy Director for Geology, Geological Survey of Iran (GSI)
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1992-1995	Research in Geotectonic Department, Laboratory of Structural Geology, University of Pierre et Marie Curie, Paris VI
1985-1998	Geological Survey of Iran Senior geologist, compiler and member of the committee of evaluation and editor of maps, reports and paper of Geological Survey of Iran, author of several reports and publications, Tehran
1975-1985	Head Geologist (Group N° 7), Geological Survey of Iran, Tehran
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