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Major metallogenic provinces and epochs of Mexico*

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*** This article contains Electronic Supplementary Material (ESM: Table 1 and List of References) downloadable at http://www.e-sga.org**

Introduction

Mineral wealth is a major asset for Mexico in both economic and academic activities. Mexico is a top producer of silver (with an unsurpassed historical production), bismuth, celestine and fluorite, a major producer of cadmium, arsenic, molybdenum, lead, zinc, barite, antimony, manganese, gold, and an important producer of copper, iron, and phosphorite. Such mineral endowment comes from a wide variety of ore deposit types and their many (often puzzling) mineralisation styles. These include epithermal, porphyry, skarn, MVT, VMS, SEDEX, and IOCG as the most outstanding types. These deposits formed as 'side effects' of geological processes that have become major shapers of the Earth's crust as we know it, like the complex and long-lasting American Cordillera build-up or the breakup of Pangea. Mexico is also an outstanding mineralogical country. Minerals range from small-sized rare minerals like boleite in El Boleo (Baja California Sur) to gigantic crystals (up to 11 m long) of much humbler gypsum in the oxidation zone of the Naica skarn (Chihuahua).

The metallogenic provinces and epochs of Mexico are loosely defined through the main physiographic provinces (namely, Sierra Madre Occidental, Sierra Madre Oriental, Sierra Madre del Sur, Trans-Mexican Volcanic Belt, Mesa Central, and the Baja California Peninsula). No matter how convenient may be to use such divisions, these units do not have a metallogenic significance on their own provided that some of them were generated as a result of the same processes, and ore generating processes might have occurred at different epochs as a consequence of very different processes within a single province. In this paper it is intended to describe the metallogeny of Mexico by means of major geological events rather than divisions that are irrelevant for the purpose of characterising ore-forming processes, albeit the 'limits' of metallogenic provinces are left deliberately blurry.

General features

Although the oldest known Mexican ore deposits date back to the Proterozoic, the metallogenically most productive geological processes started in the region during the Jurassic. Besides the seminal work by González-Reyna (1956), the metallogeny of

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MAIN FEATURES

SGA-SEG Co-Sponsored Ore Deposit Models and Exploration Short Course (1-5/11/2008) in Kunming, Yunnan, China

Xuanxue Mo (CUGB), Zhaoshan Chang (CODES) and David Leach (USGS)

SGA and SEG co-sponsored a short course on ore deposit models and exploration strategies that was held November 1-5, 2008, in Kunming, Yunnan Province, China. The organizing committee was led by Steve Scott (Honorary Professor of the China University of Geosciences, Beijing, abbreviated as CUGB). Other co-sponsors included the Yunnan Geological Survey, CUGB, China Ministry of Education Project 111 through its CUGB base, SGA, Yunnan Bureau of Geology and Mineral Resources, Yunnan Bureau of Nonferrous Geology, Mineral Resources Institute of the China Metallurgical Geology Bureau, Asia Now Resources Corporation, and the Kunming University of Science and Technology.

The instructors were Zhaoshan Chang and David Cooke from CODES, University of Tasmania, Australia; Richard Goldfarb and David Leach from the USGS in Denver, USA; Chusi Li from Indiana University, USA; Xuanxue Mo from CUGB; Steve Scott from the University of Toronto, Canada; and Noel White and Kaihui Yang from Asia Now Resources, Toronto, Canada. Joan Scott organized the laboratory sessions and dealt with logistics.

The short course covered a wide range of topics, including VMS deposits (Steve Scott and Kaihui Yang), SEDEX and MVT deposits (David Leach, Dave Cooke), iron ores (Noel White), porphyry and epithermal deposits (Dave Cooke), skarn deposits (Zhaoshan Chang), orogenic gold and Carlin-like gold deposits (Rich Goldfarb), magmatic Ni-Cu deposits (Chusi Li), ore deposits of western China (Xuanxue Mo), the importance and application of ore deposit models to exploration (Noel White) and implication of the course for exploration in China (Kaihui Yang). The short course featured a lab component with about 500 representative samples as well as maps/sections from typical deposits world-wide displayed for the course participants to inspect. A draft of a manual, "Ore Deposit Models in Mineral Exploration", originally prepared by Noel White for industry in 1998 and updated by the instructors of this short course, was distributed. The final version is expected to be published in 2009.

The short course attracted more than 300 participants from 16 China provinces and overseas, including professors and students from Chinese and Australia universities, professionals from domestic and international exploration companies and government surveys, and researchers from various institutes. The course accommodated more than 300 people which demonstrates the strong interest in China for such a presentation. The enthusiastic participants were attentive to the lectures, and the 3 display rooms were always filled with people during lab sessions. The instructors were often surrounded by participants, answering questions or discussing exploration/research issues. The lectures were mostly delivered in English with Chinese summaries/translations but, to the surprise of the instructors, many questions asked during the final panel discussions were in English.

A survey at the end of the short course showed that the majority of the participants were excited about learning modern ideas, meeting world experts, and seeing samples from renowned deposits; a few complained that the course went too fast, even though it lasted 5 exhausting days, and the venue was not comfortable, as tables had to be removed from the lecture hall to accommodate all the participants.

The short course began in 2005 as a 3-day effort preceding the SGA Biennial meeting in Beijing. In 2007, it was organized in Beijing at CUGB and it covered more topics and attracted about 300 participants. The short course was expanded again in 2008 from 3 days to 5 days, adding skarns, epithermal deposits and iron ores. It is also getting more popular. Three more universities outside of Beijing have expressed a strong interest to host the short course. It will next be held in Beijing in 2009.

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Obituary
P. Routhier (1916-2008)

Pierre Routhier, one of the founders of SGA in 1965, passed away on the 3rd November 2008.
He enrolled at the "Ecole normale supérieure (ENS)" in 1937 and presented his DES (Higher Studies Diploma) on the coalfields of Ségure and Durban (Aude, France) in May 1939, under the supervision of Louis Barrabé. Enrolled in the army, he served in a DCA battery. He went back to his activities in October 1940 and was received as major at the "Agrégation de Sciences naturelles" in 1941.
He undertook several studies on greenstones belts in Corsica, and at Saint-Véran, and began research on the Saïda Mountains in Algeria. These studies were at the origin of his interest for mineral deposits.
At the end of the war he went to New Caledonia to direct a joint CNRS-ORSOM mission, which resulted in the publication of several geological maps at the 1:100000 scale and in setting up a geological survey in Noumea.
Upon his return from New Caledonia in 1949, he became assistant at the "Laboratory of structural and applied geology" of the Faculty of Sciences of Paris. He presented his Ph.D. thesis in 1952 (published in 1953) on the peridotite massifs of the west of the island. After his Ph.D., Pierre Routhier dedicated himself to the study of mineral deposits, in particular the chromite deposit at Tiébaghi, New Caledonia (1956).
In 1955 he was hired as "maître de conferences" and was in charge of structural, applied geology and ore deposit training. In 1961, after Barrabé's death, he took over the direction of the Laboratory and undertook the development of an autonomous scientific discipline, known as Metallogeny, and now internationally acknowledged. He developed this new training program, which formed several hundreds of French and foreign students.
He travelled worldwide to study mineral deposits, and realized the need for a non-genetic classification of mineral deposits (1958). Together with André Bernard he developed the "syngenetic" school as opposed to the omnipresent "epigenetic" school.
In 1963 he published the seminal treaty "Les gîtes métallifères. Géologie et principes de recherche", a milestone in the ore deposit literature.
In 1964 P. Routhier became President of the Société de Géologie de France and was one of the founders of SGA (1965). He started several research projects on the Pb-Zn ores of the Cévennes (France) and on massive sulfide deposits of Huelva (Spain).
In 1969 he wrote "Essai critique sur les méthodes de la géologie. De l'objet à la genèse", where he introduced the concepts of consanguinity, heritage and sources of metals. In 1970, he became exploration director at the BRGM, concretizing his wish to apply his scientific knowledge to mineral exploration. In 1973 he returned to the Laboratory of applied geology and then, in 1976, as a Research Director at the CNRS, he created the research team "Metallogenic Provinces" and carried out studies on the meaning of metallogenic provinces, which were synthesized in his major textbook "Où sont les métaux pour l'avenir? Les provinces métallogéniques. Essai de métallogénie globale (1980)" (Where are the metals for the future? The metallogenic provinces. An essay onglobal metallogeny, 1984).

Adapted by M. Chiaradia and G. Beaudoin from a text of François Boyer, Colette Derré, Henri Rouvier, Jacques Thibiéroz written on 21.11.08.Published with a kind permission of the French magazine Géochronique and the authors.

The SGA website

News of the Society

SGA Ordinary Council Meeting, April 3 2009, Würzburg, Germany

J. Pašava (SGA Executive Secretary), jan.pasava@geology.cz

Status of planning for SGA 2009 in Townsville – (P. Williams)

The report was presented by P. Williams. The meeting is shaping up well. Presently, the submitted abstracts are under review process with open registration. The final schedule for orals/posters is expected in June. Four simultaneous sessions (with talks 15 min each) are planned. The fundraising group is newly supervised by Campbell McCuaig (Director, Centre for Exploration Targeting, UWA Perth). After discussion Council approved the following actions:

-wide advertisement of the Conference through pdf flyers to be distributed to SGA and SEG members, SGA website, etc. (P. Williams jointly with H. Frimmel, G. Beaudoin and M. Chiaradia)

-urging the reviewing process in sessions where it is late (e.g., VMS – P. Williams),

-providing seed money in the amount of 5000 USD to E. Campos to participate in the Townsville meeting (P. Williams/D. Leach),

-moving the presentation of SGA Awards from Opening Ceremony to SGA General Assembly (August 19, Wednesday afternoon – time and venue to be specified – P. Williams jointly with D. Groves),

-offering short course and field trip organizers editorial assistance in the case they want to have their publications published on and/or sold through SGA website (P. Williams/R. Foster - following the Council's decision to establish a series of publications "SGA Excursion Guidebook No.1 Title xxxx" and "SGA Short Course No.1. Title xxxx" and approval of Robert Foster to become Publication Manager).

Council approved the report with great thanks.

More detailed info on the meeting can be found on pages 23-28 and is displayed at the http://sga2009.jcu.edu.au/.

Status of planning for SGA 2011 in Antofagasta, Chile – (E. Campos, F. Tornos)

The report was presented by F. Tornos. After discussion Council approved the following actions:

-set up the exact date of the meeting as soon as possible so that it would not collide with dates of major international geo-events (Goldschmidt, Fermor, SEG, IAGOD and others) – F. Tornos/E. Campos;

-prepare a simple eye-catching flyer to advertise the 11th SGA Biennial Meeting (Antofagasta, Chile) in Townsville (E. Campos/F. Tornos/H. Frimmel);

-revise the composition of the LOC (add A. Vymazalova and J. Relvas to Students Committee, E. Ferrari and D. Leach to Sponsorship Committee, A. Piestrzynski and M. Chiarardia to Courses Committee, B. Lehmann to Field trip Committee, P. Williams to Technical Sessions Committee, H. Frimmel to Advertising Committee – E. Campos/F. Tornos);

-target for about 8 short courses/workshops that could be recycled in the future – E. Campos/F. Tornos;

-target for a balance between thematic and geographically oriented field trips (offer about 10 field trips – people will decide which of them will be realized) – E. Campos/F. Tornos;

-prepare a draft of the MOU between the SGA and the LOC (Antofagasta 2011) so that it could be translated into Spanish and signed with relevant representative of the LOC in Townsville.

Reports of officers on Council and matters arising from these reports

Reports were submitted by SGA Executive Secretary , Treasurer's Office, Promotion Manager, Editor of the SGA News, Editor of SGA Website including e-shop, and VP for Australia/Oceania, Europe, North Africa, North America, South Africa and South America.

After discussion Council approved the following:

-Regional Vice Presidents are encouraged by H. Frimmel - SGA Promotion Manager to select important mineral deposit events in their region and contact SGA Promotion Manager to receive promotional material (portable SGA booth and other items).

-SGA Council members are encouraged to contribute to upcoming SGA News (deadline – May 1, 2009 – send your MS to M. Chiaradia). SGA News no. 25 has to be ready for distribution with MD at the end of June (M. Chiaradia).

-R. Foster became SGA Publication Manager with the aim to establish a series of publications that will be of benefit to our members and also add some degree of prestige to both the writers/editors of the items and to the SGA publications record. This will initially be achieved by "creating" two sets of publications – "SGA Excursion Guidebook No.1. Title xxxx" and "SGA Short Course No.1. Title xxxxx". Actual content and draft production will rest largely with the original provider/author but the SGA is prepared to take the working draft and re-format it to an SGA-agreed standard and generate a cover title page.

-Council expressed an interest in collaboration with the 2011 GAC-MAC LOC and nominated A. Conly (RVP North America) to become Council link to discuss more details with the LOC (D. Groves will inform M. Hannington).

Council approved all reports with great thanks. Special thanks went to both D. Leach and S. Lange for excellent management of the SGA treasury over the years.

Editorial matters (B. Lehmann, P. Williams)

The report was presented by B. Lehmann and P. Williams. Journal production is on time and runs smoothly. Several thematic issues are in preparation. In order to increase IF it was recommended to go for high-profile and/or good review papers. Recent efforts by D. Groves, R. Large, P. Williams and others resulted in Mineralium Deposita rising to a B grade in the Australian ARC rankings. Council approved the report with great thanks.

Summary of important events in 2008 (J. Pašava)

The summary was presented by J. Pašava.

Progress report on membership drive in 2008 (P. Eilu, J. Pašava, A. Vymazalová)

The report was presented by P. Eilu. Great thanks to all Council members who followed the approved SGA Membership Drive suggested by D. Groves. This initiative showed up to be a great success and resulted in a total of 904 SGA members at the end of 2008 SGA (644 members in the year of 2000).

Report on nominations for SGA Awards in 2009 (D. Houston et al.)

The report was presented by J. Pašava and F. Tornos. After discussion Council approved the following:

-The maximum birth date will be indicated on SGA website for future candidates for SGA-Newmont Young Scientist Award.

-Future candidates for SGA-Barrick Gold Medal can be recipients of an equivalent awards from SEG or similar organizations.

-All future nominations for both the SGA Awards that will be received by the Award Subcommittee by the deadline will then be ranked by the Committee so that the Council will receive usually up to 5 nominations for the final vote.

-Motion on determining and contacting recipients of the 2009 SGA Awards was approved. The SGA President (D. Groves) will notify awardees, ask for citations and inform and invite representatives of both sponsoring mining companies to participate in the presentation of the awards.

Council approved the report with great thanks.

Report on nomination of the best paper in MD (B. Lehmann and P. Williams)

The report was presented by B. Lehmann with additions of P. Williams. After a discussion, Council approved that the paper by Reich M, Palacios C, Parada MA, Fehn U, Cameron EM, Leybourne MI, Zuniga A (2008) Atacamite formation by deep saline waters in copper deposits from the Atacama Desert, Chile: evidence from fluid inclusions, groundwater geochemistry, TEM, and 36Cl data. MD 43: 663-675, will receive the award. The award consists of a certificate, EUR 1500 and travel expenses for the first author associated with the receipt of the award. Council approved the report with great thanks.

Policy on student chapters (A. Vymazalová and J. Relvas)

The document was presented by A. Vymazalová with additions of J. Relvas. After a broad discussion Council recommended that SGA should create its own unique identity and distinctive benefits of membership and suggested to develop a new concept of "SGA Student/Young Scientist Regional Networks" (e.g., European SGA Student/Young Scientist Network linking active Prague Chapter with possibly other Universities in Germany, Poland, Scandinavia, UK, and other European destinations and then, if concept works well, progress it in the Americas and elsewhere). The advantages of such a scheme would include:

*Economies of scale - Chapters combining finances and personnel (including related university staff perhaps providing various levels of support) to create viable and proactive larger groupings - especially valuable in the early stages of setting up the Chapters, as individual Chapters would not have to stand alone as isolated entities.

*Greater scope for valuable networking via field excursions, regional student meetings, etc.

*Greater interchange of ideas and information between students and also between their respective departments and staff - shared student views on teaching, better opportunities for field excursions at undergrad level, enhanced interaction at post-grad level.

*Following on from the above, enhanced opportunities to visit areas/regions of metallogenic interest - where a particular university has good local knowledge and contacts/interests/expertise, all of which could be used to underpin excursion planning and even joint teaching and research initiatives in the longer term.

A. Vymazalová then presented the Report of Activities of the Prague Chapter. This very active Chapter has presently 27 members. Council greatly appreciated recent significant increase in membership and approved EUR 1500 for 2009 activities.

Any other business

o SGA proceedings listed in ISI Thomson database.
o Journal Elements (F. Tornos).
o Internal report on the XIV Congreso Geológico del Perú with additional thoughts (F. Tornos et al.).
o SGA insurance (D. Leach, D. Groves).
o Improvements of membership application form (F. Tornos et al.).
o Proposed list of SGA officers for SGA ballot 2009- Council vote (D. Groves et al.). J. Pašava presented on behalf of D. Groves (Chair of the Nominating Committee) a list of nominations for upcoming SGA ballot that resulted from work of the Nominating Committee with input of Council members and SGA membership. Council approved the list with a great thanks to all members of the Committee.
o SGA General Assembly at Townsville (Wednesday, August 19 from 2.30 pm).

J. Pašava presented suggested program of the GA, which had to be adapted because of the Council decision to present both the SGA Awards at the beginning of the SGA GA. The SGA GA will be held on Wednesday, August 19 from 2.30 pm. The venue will be announced in due time.

Date and place of the next Council Meeting

The next Council meeting will be held in Townsville, Australia on Sunday, August 16, from noon to 6.00 pm in Coral See Room of Jupiter Hotel.

LIST OF NEW SGA MEMBERS (NOVEMBER 18, 2008-MARCH 31, 2009)

23 Regular Members, 29 Student Members and 1 Senior Member applied for membership from November 18, 2008 to March 31, 2009

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>>>page 1 ***Metallogenic provinces and epochs of Mexico***

Mexico has been addressed by several authors at regional scales (Salas, 1975; Clark et al., 1977, 1982; Clark and de la Fuente, 1978; Fabregat-Guinchard and Cortés-Guzmán, 1978; Clark and Damon, 1979; Damon et al., 1981a; González-Partida and Torres-Rodríguez, 1988; Miranda-Gasca, 2000; Staude and Barton, 2001; Clark and Fitch, 2009), or regarding specific types of deposits (Damon et al., 1980, 1981b; Mead et al., 1988; Megaw et al., 1988; Albinson et al., 2001; Camprubí et al., 2003; Singer et al., 2005; Camprubí and Albinson, 2006, 2007; Ortiz-Hernández et al., 2006; Valencia-Moreno et al., 2006, 2007; González-Sánchez et al., 2007, 2009). Different criteria have been used to characterise and categorise ore deposits in Mexico, but an approach regarding major geologic events and deposit types has not been integrally attempted. The most comprehensive and useful review to date is due to Clark and Fitch (2009), rooted in the prodigious work of the Kenneth Clark and Paul Damon's team in the late 1970 and early 1980 decades (Clark et al., 1977, 1982; Damon et al., 1981a, b). Also, Francisco Fabregat compiled a large collection of data to produce regional commodity maps of economically productive Mexican ore deposits (Fabregat-Guinchard and Cortés-Guzmán, 1978). In general, most of ore deposits in Mexico are due to either (1) the convergent plate margin along the Pacific coast and the resulting magmatic activity since the Jurassic, or (2) the fluid dynamics and geochemical processes in the sedimentary basins that are part of the Gulf of Mexico mega-basin, that also hosts the Mexican oil and gas fields. Although such processes are held accountable for the vast majority of ore deposits in Mexico, there are other types of deposits, like 'Cordilleran' orogenic gold deposits or rare-element pegmatites, that formed in other contexts and epochs. Also, significant events like the opening of the Gulf of California and the subsequent incorporation of the Baja California Peninsula to the Pacific Plate generated shallow submarine deposits on the western side of the Gulf.

The geological configuration of Mexico can be schematised as a grouping of tectonostratigraphic terranes, which have a wide variety of volcanosedimentary series associated with several Mesozoic and Cenozoic magmatic arcs. Such terranes might have attached to ('accreted') and detached from the mainlands during the complex evolution of the Pacific margin in Mexico (Centeno-García et al., 2008). The core paleocontinent for the gathering of such terranes is named Oaxaquia, and it is thought to extend NNW-SSE from Coahuila to Oaxaca (Fig. 1). The complex structural arrangement of Mexico determined the existence of fault or discontinuity zones at different crustal scales that have acted episodically as preferential channelways for magmas and aqueous fluids over a long period of time. This might have been the case of major suture zones between terranes, and is also the case of large (more than 700 km long) fault zones bordering the region known as Mesa Central or Mexican Altiplano. These were dated to the Eocene-Oligocene, show neotectonic activity, and it is speculated that they may be inherited from Cretaceous or older structures (Nieto-Samaniego et al., 2005, 2007) that may be associated with suture zones between terranes. The role of these large fault zones in ore-forming processes is yet to be firmly established in this region, but the preferential accumulation of several types of ore deposits around large fault zones suggests that they ruled to a great extent the upflow of magmas and fluids, and the emplacement of mineralisation.

From the Proterozoic to the Jurassic

Known Proterozoic ore deposits are virtually restricted to anorthosites (Ti) and rare-element pegmatites (U-Th-Nb-Ta-REE) in the Oaxacan Complex. Rare-element pegmatites are found in the region between Huitzo and Telixtlahuaca, including the notorious El Muerto pegmatite, formerly mined for U and Th. Two sets of pegmatites in the region were dated by Solari et al. (2003) at 1153-1063 Ma and 980-956 Ma. Ti-rich anorthosites in the Pluma Hidalgo region were dated at 1010-998 Ma by Schulze et al. (2000). Paleozoic ore deposits are also scarce. The Carboniferous (Visean) VMS deposits in Teziutlán (Puebla) have been characterised as Besshi type deposits (Miranda-Gasca, 2007) and are regarded almost as an isolate case for their kind. However, the economically most important Paleozoic deposits are the Late Devonian SEDEX barite deposits in Sonora (Johnson et al., 2009). The serpentinites and refractory grade PGE-poor chromitites in Tehuitzingo (Puebla) are part of a slice of an ophiolitic sequence from a supra-subduction zone (Proenza et al., 2004) that probably was obducted during the Early Ordovician (Campa-Uranga et al., 2002) as part of a regional-scale event (Vega-Granillo et al., 2007). There are other Paleozoic Cr-Ni-Cu-Co-PGE showings in mafic-ultramafic complexes in Sinaloa, and Late Triassic to Middle Jurassic in Baja California Sur, as well as numerous Jurassic and Cretaceous examples, mostly associated with ophiolites or intra-oceanic arcs (Ortiz-Hernández et al., 2006).

The „backbone" metallogenic province: the Pacific margin

The deposit types that can be genetically attributed to magmatic processes taking place mostly in continental arcs (Jurassic to recent) in the Pacific margin of Mexico are chiefly (1) polymetallic or Ag-Au epithermal, (2) porphyry Cu, Mo, Au, W, (3) polymetallic or Au skarn, (4) volcanogenic stratiform massive sulphide or barite (VMS), (5) magmatic/hydrothermal iron oxide (IOCG 'clan'), (6) Sn veins or disseminations associated with granites or rhyolites, and (7) U(-Au) veins in rhyolites. The above deposit types are located along a wide NW-SE magmatic belt across the country that evolved from mostly submarine oceanic to immature continental arcs in the Mesozoic, to subaerial continental arcs since the Late Cretaceous. It includes the silicic large igneous province (SLIP) of the Sierra Madre Occidental (SMO), the Sierra Madre del Sur (SMS), and the Sierra Madre de Chiapas (the western and southern Sierras Madre).

Among other characteristics, this is the greatest silver province in the world. The likeliness that 'all' the epithermal deposits in the region (the greatest silver producers) are genetically linked to magmatism, beyond its role as a source for heat, is arguable. Conventional models for epithermal deposits agree with non-magmatic sources for fluids, ligands, and perhaps metals, and with the idea that these deposits may not have formed in association with continental arc magmatism (e.g., the San Felipe deposit in Baja California). However, the available data allow us to make the simplifying assumption that there is a suite of ore deposits, that encompasses porphyry, skarn, epithermal and VMS types (among others), which are associated with arc-related calc-alkaline (also adakite-like) to alkaline magmatism.

In this paper, skarn deposits stand for either mantos, chimneys or skarn-type in the sense of Megaw et al. (1988) and Clark and Fitch (2009), as well as 'distal skarns'. The morphology, structure, and metal contents of

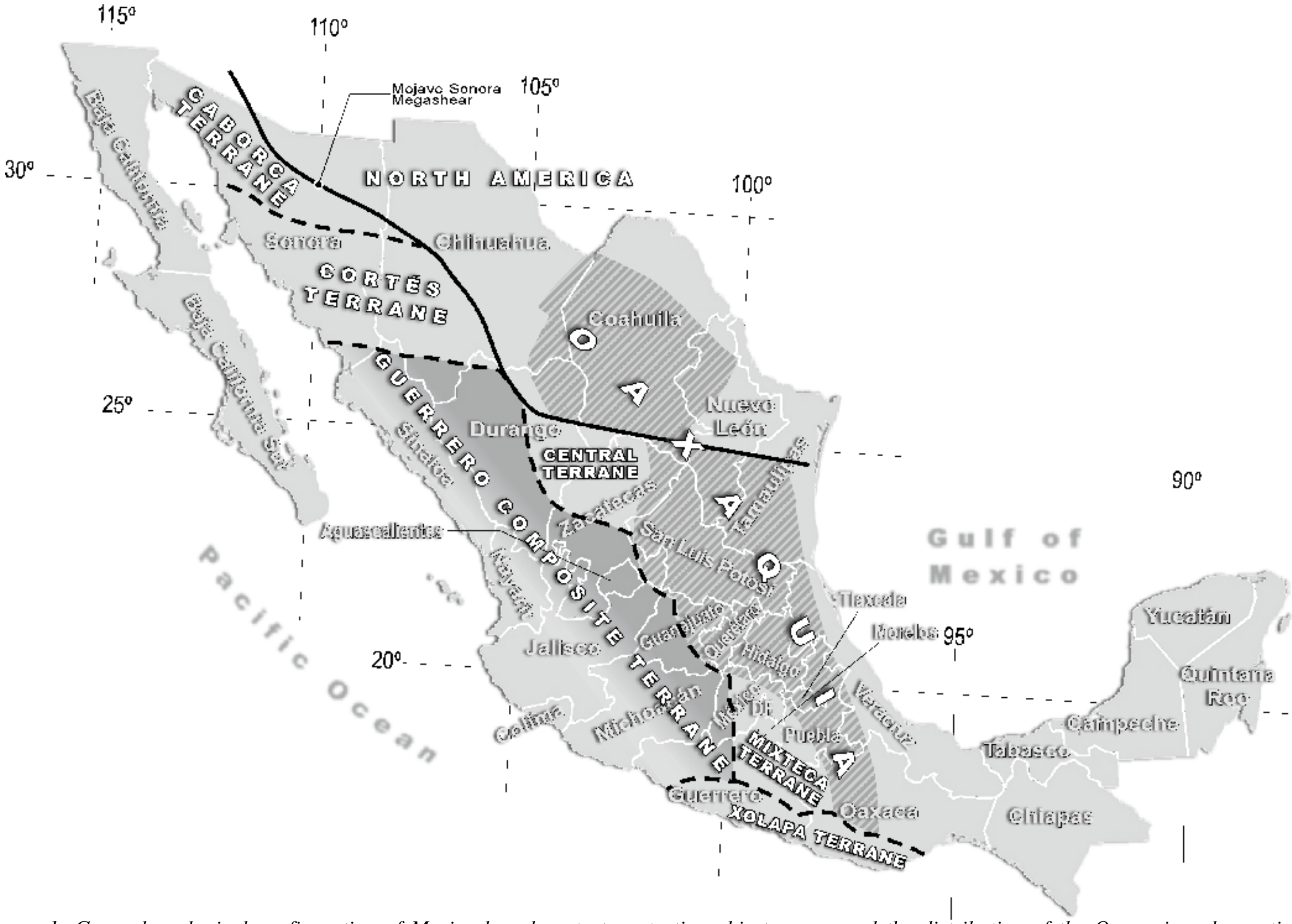


Figure 1: General geological configuration of Mexico based on tectonostratigraphic terranes and the distribution of the Oaxaquia paleocontinent, simplified from Centeno-García et al. (2008).

the diverse skarn styles differ largely from each other, but all these differences fit in a single genetic type, as much as it happens with epithermal deposits (Camprubí and Albinson, 2006, 2007). The term 'carbonate replacement deposits' may be misleading as it describes skarns as much as epithermal, MVT or other types, although Megaw (1998) provided a comprehensive definition for them.

The Mesozoic-Cenozoic magmatic activity in the Pacific margin can be divided into five major episodes (Ferrari et al., 2005b, 2007; Morán-Zenteno et al., 2005, 2007; Centeno-García et al., 2008): (1) Jurassic to Early Cretaceous, (2) Late Cretaceous to Paleocene, (3) Eocene-Oligocene, (4) Early Miocene, and (5) Middle Miocene to present in the Trans-Mexican Volcanic Belt (TMVB), that contains recent and active volcanoes.

Subduction in the region began in the Early Jurassic and formed several island arcs and volcanosedimentary assemblages (Centeno-García et al., 2008). In submarine volcano-sedimentary assemblages, that extend into the Cretaceous, several volcanogenic-hosted massive sulphide deposits (VMS) are found, like Tizapa, Campo Morado, Tlanilpa-Azulaquez, San Nicolás-El Salvador, and Cuale (Fig. 2). Another set of deposits (La Minita, Sapo Negro) contains sulphides at its base, massive barite in most of the deposit, and Mn and Fe oxides at the top, thus reflecting a progressive oxidation. Some VMS deposits formed in a back-arc setting between the volcanic arcs and the epicontinental seas and positive lands of eastern Mexico, and others formed within juvenile and slightly evolved arcs (Mortensen et al., 2008). In the case of Cuale, a shallow submarine epicontinental environment is invoked (Bissig et al., 2008). Most of the VMS deposits in Mexico are classified as Kuroko-type deposits, although Copper King may belong to the Cyprus type (Miranda-Gasca, 2000). These deposits formed in association with either calc-alkaline, tholeiitic or alkaline volcanic rocks (González-Partida, 1993), although the time and space distribution of such rock types is not well known.

In general, during the Early Cretaceous Cr-Ni deposits formed in mafic-ultramafic rocks in island arcs (Ortiz-Hernández et al., 2006) and metalliferous porphyries in continental arcs (Valencia-Moreno et al., 2006, 2007). However, the Cretaceous-Paleocene belt contains mainly porphyry and skarn deposits. Evidence for primitive arc emplacement is found at the Early Cretaceous El Arco-Calmallí porphyry deposits (Weber and López-Martínez, 2006). A few epithermal deposits were formed: El Barqueño (mostly low sulphidation), and Caridad Antigua (high sulphidation), which telescopes the La Caridad porphyry Cu deposit. The giant porphyry Cu-Mo(-W) deposits in Northern Sonora (e.g., Cananea, La Caridad) are part of the 'Big Cluster' that contains the porphyry deposits in southeastern Arizona and southwestern New Mexico, like Bisbee and Morenci. Porphyry deposits in Mexico are apparently cogenetic with their 'parental' batholiths. Their geochemical signatures indicate that the magmas may have been derived from different sources and magmatic processes, and display different degrees of crustal contamination and assimilation of sedimentary materials (Valencia-Moreno et al., 2006, 2007; Zürcher and Titley, 2007; Potra and Macfarlane, 2008). In SW Mexico there is a significant concentration of iron deposits (the iron belt of Damon et al., 1981a; Clark et al., 1982) that have been described as skarns like Mezcala or Cerro Náhuatl or 'generic' magmatic-hydrothermal magnetite-apatite

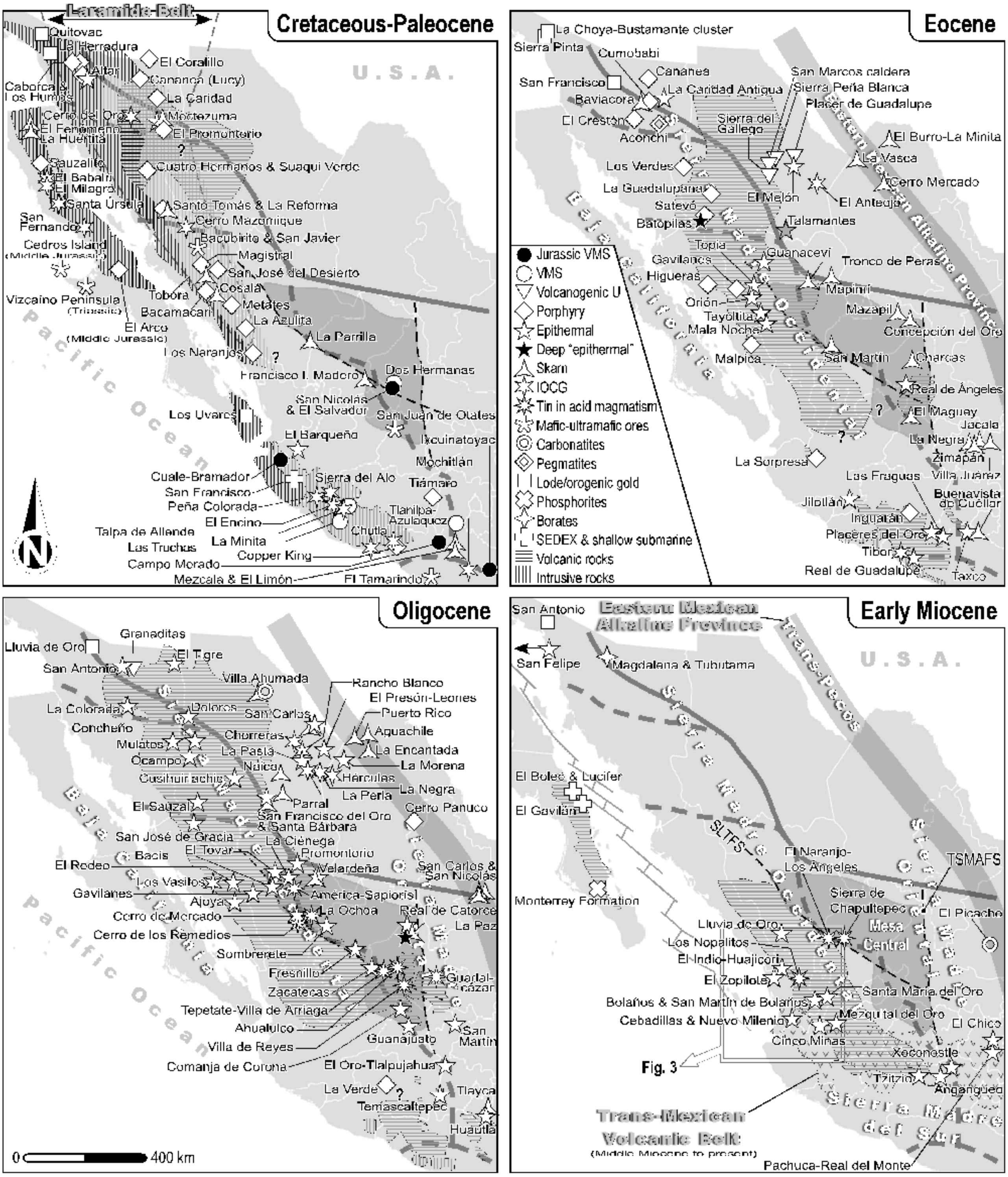


Figure 2: Age and geographic distribution of magmatism and genetically related ore deposits in the Pacific convergent margin of Mexico, and in the Gulf of California. The distribution of volcanic and intrusive rocks was taken from Ferrari et al. (2005b, 2007) for the Sierra Madre Occidental and Morán-Zenteno et al. (2005, 2007) and Martínez-Serrano et al. (2008) for the Sierra Madre del Sur. The position of the Baja California Peninsula is reconstructed to its approximate pre-rifting position except in the lower right map, where it is shown in its present position. All the deposits in the maps have radiometric age determinations or their age is well constrained by means of plausible geologic correlation (shown in Table 1), with only a few exceptions that might reasonably formed during the period they are consigned to. The El Boleo and El Gavilán deposits in the Baja California Peninsula are not associated with arc magmatism but with continental extension instead, and the Monterrey Formation is constituted by sedimentary phosphorites; such deposits are shown here to complete the metallogenic overview of the region. The Jurassic VMS and older deposits are shown in the Cretaceous-Paleocene but are obviously unrelated to such magmatism. The Trans-Mexican Volcanic Belt (TMVB, Middle Miocene to present) is shown in order to indicate the extent of the previous igneous belts that are covered for it. The Xoconostle and Tzitzio deposits are genetically associated with the TMVB, not with the volcanism of the Sierra Madre Occidental. In the upper left map, patterns in black denote the extent of outcrops, and in grey are covered rocks; in the rest of maps are shown the known occurrences alone. In darker grey it is indicated the approximate area of the Mesa Central, taken from Nieto-Samaniego et al. (2005, 2007). The Talamantes Mn deposit is identified with a grey star as a suitable candidate to belong to the epithermal type, although the author could not confirm such filiation. Thick grey lines denote terrane boundaries as in Fig. 1. Key: SLTFS = San Luis-Tepehuanes Fault System; TSMAFS = Taxco-San Miguel de Allende Fault System.

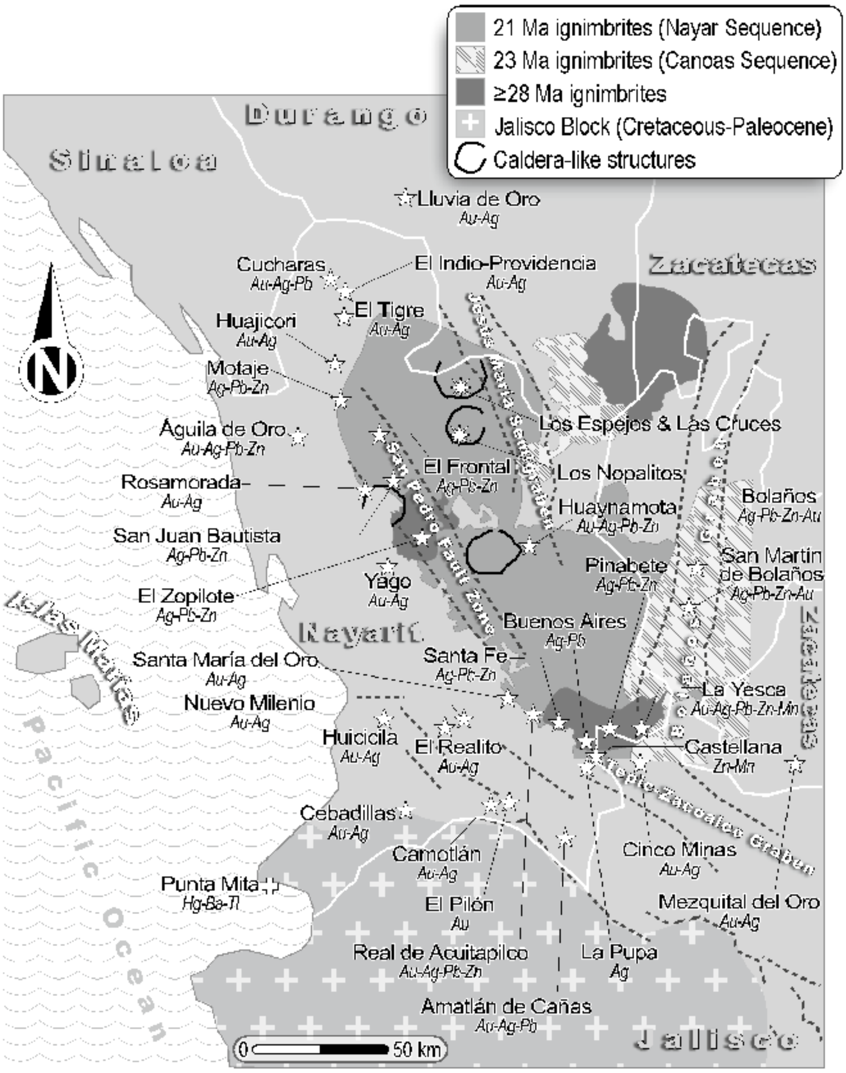


Figure 3: Geographic distribution of plausible Miocene epithermal deposits in SW Mexico (after Aguilar-Nogales, 1987), Oligocene-Miocene ignimbrites of the latest magmatic pulses of the SMO in the area, and major structural features (simplified from Ferrari et al., 2005b, 2007). Same symbols as in Fig. 2.

deposits like Peña Colorada, El Encino or Zaniza. The available ages in southwestern Mexico (Camprubí et al., 2006a) suggest an Early Paleocene magmatic event responsible for such concentration of deposits, and might have generated other types of deposits as well. Hernández-Barosio (1979) explained the formation of such deposits in southeastern Mexico mostly as due to magmatic 'segregation and injection' during the Paleocene-Eocene. Iron skarns could actually be part of the broad and loosely characterised iron oxide-copper-gold (IOCG) clan, in the same fashion as similar deposits in the Andean Coastal Ranges (Sillitoe, 2003). The occurrence of tholeiitic gabbro-diorites in southwestern Mexico coeval to most iron deposits advocates for continental extension and crustal thinning in the region during the Paleocene, thus suggesting an Andean-like IOCG setting. Also, tholeiitic and calc-alkaline rocks were emplaced in the same region simultaneously (Zürcher et al., 2001; Corona-Esquivel and Henríquez, 2004). In the Alisitos arc, Baja California, gabbros are also reported in association with parental magmatic rocks for the Early Cretaceous San Fernando IOCG deposit, which probably formed during a brief continental rifting period at 111-110 Ma (see Lopez et al., 2005; here I interpret the rifting event described by Busby et al., 2006, as the most likely to have associated IOCG deposits) or later during a compressional event (Cruise et al., 2007). Other iron deposits in southwestern Mexico with unconstrained ages are likely to belong to the Paleocene IOCG cluster too: Las Truchas, La Guayabera, Aquila, Tibor, and Plutón.

The magmatism during the Eocene moved eastwards into the continent (Fig. 2), and doing so it reached the carbonate sequences that formed in epicontinental basins related to the passive margin of the Gulf of Mexico. In distal portions of the magmatic belt, the intrusive bodies associated with the Eocene episode in contact with carbonate rocks therefore formed some of the biggest Zn-Pb-Cu-Ag skarn deposits in the country, like Zimapán, Mapimí, Charcas, Concepción del Oro, and San Martín, and the same occurred during the Oligocene. This belt also includes the Au-bearing polymetallic Peñasquito skarn in Mazapil, soon to be one of the largest mining developments in Mexico. Some skarns in Sonora with other deposit types altogether, Paleocene to Oligocene in age, are rich in W (Mead et al., 1988). Meanwhile, porphyry type deposits kept forming in proximal portions of the magmatic belt. Epithermal deposits also formed, with a cluster of important deposits in the central part of the SMO (Tayoltita, Topia) and in the SMS. The Eocene episode constitutes the first bimodal andesitic-rhyolitic volcanic episode of the Lower Volcanic Complex (LVC) of the SMO (e.g., McDowell and Keizer, 1977). The LVC extends into the Eocene and is largely formed by andesites and, locally, rhyolitic volcanic centres which are generally associated with economically relevant epithermal deposits.

The climactic magmatism in the SMO is represented by ignimbritic silicic volcanism in two main pulses: (1) from Late Eocene to Early Oligocene along the entire SMO and the Mesa Central, and (2) during the Early Miocene in the central and southern SMO. A myriad of epithermal deposits formed in association with the first pulse, with a preferential age range between 35 and 30 Ma in the Mesa Central, including world-class districts as Guanajuato and Fresnillo (currently the biggest silver mine in the world). Actually, this age range is the most prospective for epithermal deposits in Mexico. Also, tin deposits associated with the emplacement of rhyolitic domes or granitic intrusions (greisen) are virtually restricted to the borders of the Mesa Central (specifically to the San Luis-Tepehuanes Fault Zone; Nieto-Samaniego et al., 2005, 2007) and formed during the Oligocene crustal extension period as well. Among them, the Tlaquicheros, Villa de Reyes, Villa de Arriaga, Ahualulco, Cosío, Sierra de Chapultepec, La Ochoa, Juan Aldama, Cerro de los Remedios, Sombrerete, Avino, and El Naranjo-Los Ángeles deposits are worth mentioning. During the Oligocene a second set of IOCG deposits in the southern and northeastern SMO (Fig. 2; Cerro de Mercado, and the La Perla-Hércules cluster, respectively) formed. The Paleocene IOCG deposits appear to be of relatively deep formation, as they commonly contain coarse euhedral magnetite with incipient

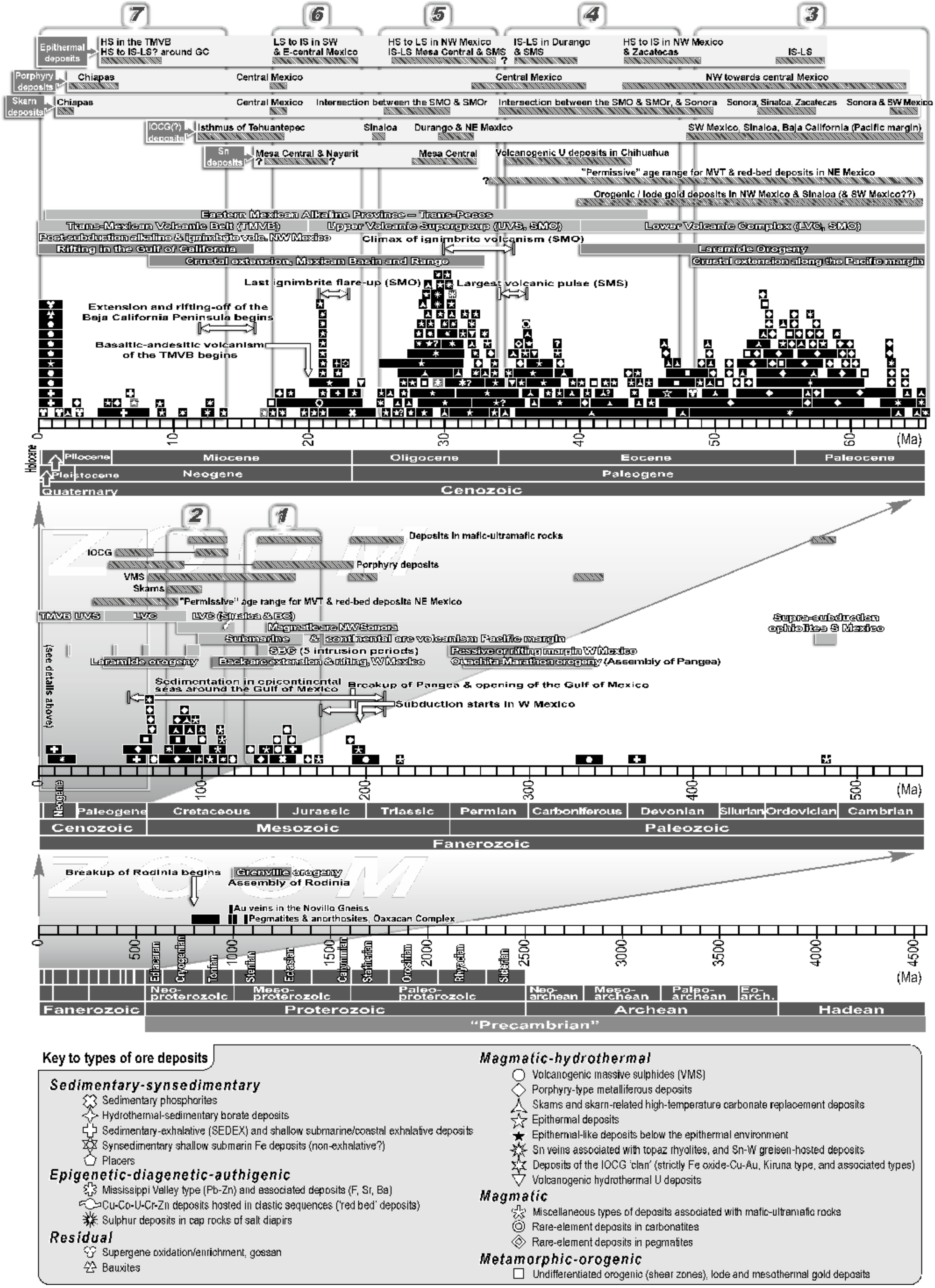
Figure 4: Geographic distribution of ore deposits associated with the evolution of the Gulf of Mexico, based on González-Sánchez et al. (2007, 2009) and Rocha-Rocha (2008). The extent of the basin is only approximative, with the purpose to show the occurrence of the sedimentary facies to which the ore deposits are genetically associated or hosted by them. The Campeche Sound and the Chicontepec Basin contain most of the oil and gas fields in Mexico. Thick grey lines denote terrane boundaries as in Fig. 1. Key: BPP = Burro-Peyotes Paleopeninsula; CPI = Coahuila Paleoisland; LBF = La Babia Fault; MSM = Mojave-Sonora Megashear; SLVP = San Luis-Valles Platform; SMF = San Marcos Fault; TSMAFS = Taxco-San Miguel de Allende Fault System.

martitisation and may be considered 'hypabyssal' (e.g., Peña Colorada; Tritlla et al., 2003), whereas Oligocene deposits have clear volcanic structures (e.g., Cerro de Mercado; Lyons, 1988) or consist mostly of ash-fall pulverulent hematite deposits (e.g., La Perla; Cárdenas-Vargas and del Castillo-García, 1964).

The Early Miocene magmatic pulse corresponds to the last volcanic episode in the SMO that is clearly ignimbritic, known as Upper Volcanic Series (McDowell and Keizer, 1977). During this event mostly epithermal deposits are known to have formed (Fig. 2). Most Miocene epithermal deposits are found in Nayarit, along with some Sn veins associated with Miocene calderas (Fig. 3). These deposits are probably associated with the continuous volcanism that occurred between 19.55 and 12.6 Ma (Aguilar-Nogales, 1987). The second important prospective area for Miocene deposits is found at the eastern end of the TMVB, and encompasses epithermal deposits like Pachuca-Real del Monte, skarn, porphyry and IOCG deposits. The Pachuca-Real del Monte district is the largest silver-producing single ore deposit ever (~45,000 t Ag, 220 t Au). The reason for such exceptional amount of silver in a single district, especially in such an uncommon place and time for epithermal deposits in Mexico, is unknown. East of Pachuca, the Ixtacamaxtitlán area (Puebla) contains small porphyry gold (dated at 17.8 Ma) and skarn deposits telescoped by a low sulphidation epithermal deposit, and an iron oxide-gold-copper 'skarn' (that is, IOCG) telescoped by polymetallic epithermal veins in Tatatila-Las Minas (Veracruz) that may be younger than 11 Ma.

The Eastern Mexican Alkaline Province (EMAP), Late Eocene to Present, forms a belt parallel to the Pacific paleotrench by the Gulf of Mexico and comprises some alkaline intrusive and volcanic complexes with ages decreasing southwards. The EMAP reflects a switch in magmatism from subduction to intraplate due to continental extension and slab rollback (Ramírez-Fernández et al., 2000; Viera-Décida et al., 2009), as a southwards prolongation of the controversial Río Grande Rift. In northern Mexico, it contains REE carbonatites, agpaites and alkaline metasomatism at El Picacho and Villa Ahumada (Rubinovich-Kogan et al., 1988; Nandigam et al., 1999; Ramírez-Fernández et al., 2000) and, according to the possibility that carbonatites may be part of the IOCG clan (Groves and Vielreicher, 2001), it would not be unlikely that the metallogenic belt of the EMAP includes the deposits in the La Perla-Hércules cluster. In addition, the prevailing tectonic regime during the formation of these deposits was extensional (Labarthe-Hernández and Tristán-González, 1988). Further study may also explore the possible genetic link between IOCG and epithermal deposits in northeastern Chihuahua. In northern Coahuila, a group of Eocene to Oligocene polymetallic (Zn-Pb-Cu-Ag-Au) skarn deposits (Fig. 2) are due to alkaline magmatism as well, and some of them are rich in Co-Ni-Cr. In the southern part of the EMAP, in the

Figure 5 (next page): Histographic representation for the occurrence in time of ore deposits in Mexico with known ages, based on Table 1. The black boxes cover the time span obtained in individual deposits or overlying/underlying rocks. The time span of major geologic events was drawn from Henry et al. (2003), Ferrari et al. (2005b, 2007), Morán-Zenteno et al. (2005, 2007), and Centeno-García et al. (2008). The two available analyses from Caballo Blanco (Veracruz) are shown in grey boxes for reasons explained in Table 1. Although this deposit is marked here as epithermal, it is not known whether the analysed rocks were more closely associated with the epithermal or the porphyry mineralisations. Also in grey, MVT deposits whose association with the dated rocks is poorly understood. Key: GC = Gulf of California; HS = high sulphidation; IS = intermediate sulphidation; LS = low sulphidation; LVC = Lower Volcanic Complex (SMO); MVT = Mississippi Valley type deposits; SBC = Sinaloan Batholithic Complex; SMO = Sierra Madre Occidental; SMOr = Sierra Madre Oriental; SMS = Sierra Madre del Sur; TMVB = Trans-Mexican Volcanic Belt; UVS = Upper Volcanic Supergroup (SMO).



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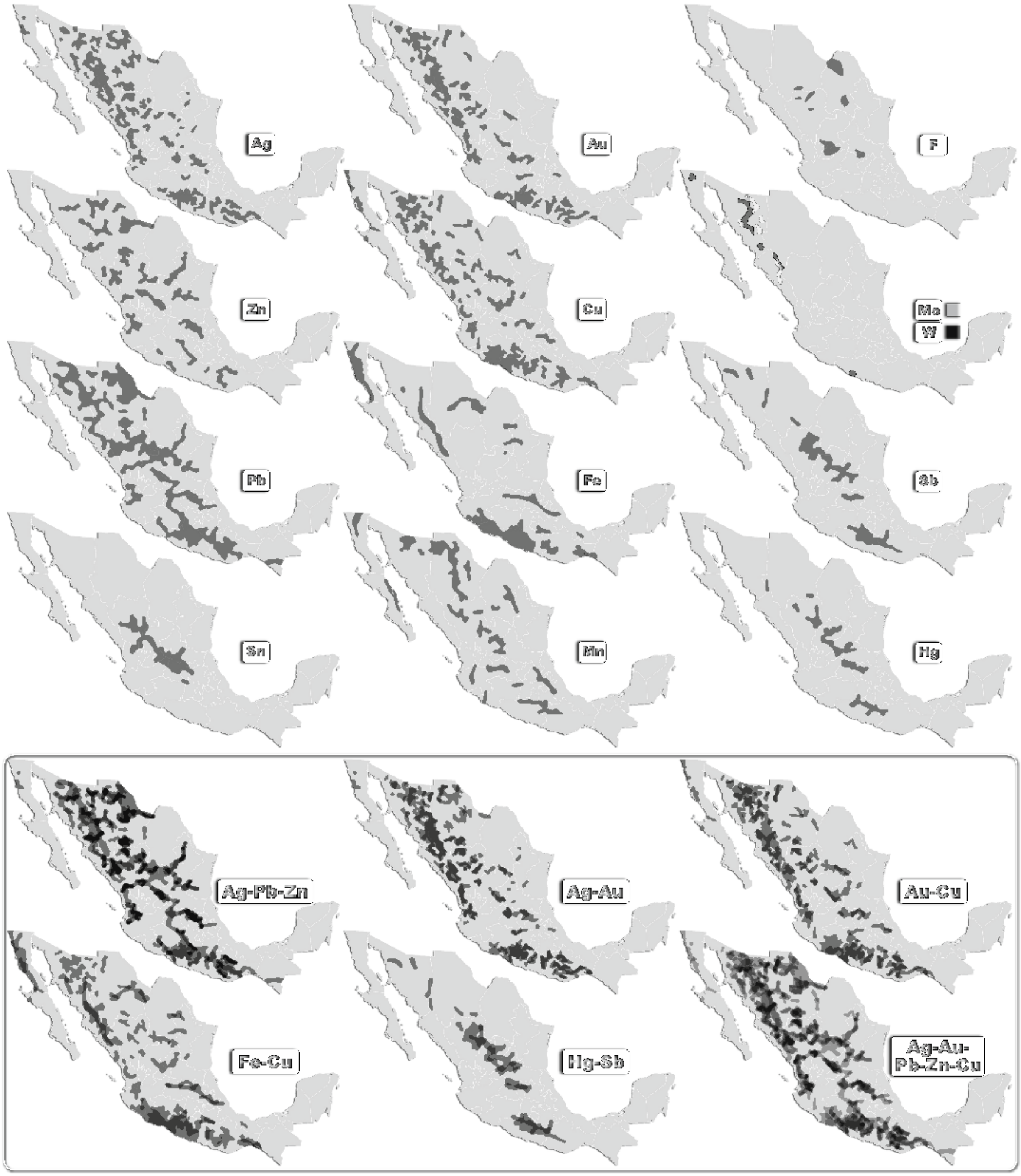

Figure 6: Elemental distribution in Mexican ore deposits and their combination in characteristic metal associations, as obtained by Fabregat-Guinchard and Cortés-Guzmán (1978) after the analysis of over 5,000 economic mineral deposits.

Palma Sola region (Veracruz), an alkaline magmatic complex (dated at 17.0 and 7.48 Ma; Negendank et al., 1985; Ferrari et al., 2005) hosts a group of porphyry and high-sulphidation epithermal deposits currently under exploration that are similar to those in the southwest Pacific (e.g., Richards and Kerrick, 1993; Richards, 1995). Similar to the above, the porphyry and epithermal deposits in the Ixhuatán area (Chiapas; Miranda-Gasca et al., 2005) may represent the southernmost end of the EMAP metallogenic belt.

It is worth to remark that some deposits in central Mexico (porphyry and epithermal deposits: Caballo Blanco, Tzitzio, Xoconostle) and in Chiapas (porphyry and skarn deposits: Ixhuatán, Santa Fe) are associated with recent magmatism of either the TMVB or the EMAP (Table 1 and Fig. 5). The reason for this is that the general prospectiveness or likeliness to host relevant ore deposits of the TMVB has been traditionally overlooked or misprised, although its magmatism of variable mafic to felsic composition (Gómez-Tuena et al., 2005, 2007) makes it a good candidate to host ore deposits of the 'calc-alkaline suite' (Camprubí and Albinson, 2007).

The geothermal fields in Central Mexico and the Baja California Peninsula represent appropriate modern analogues for shallow epithermal deposits. Metallic mineral associations have also been described in active volcanoes: Taran et al. (2000) reported gold as a sublimate in the Colima volcano and Larocque et al. (2007) described metallic mineral associations similar to those in high sulphidation epithermal deposits in pumice fragments of the Popocatépetl.

Thus, the metallogenic history of the Pacific convergent margin in Mexico can be very roughly sketched since the Jurassic as a succession of VMS-, porphyry-, skarn-, and epithermal-dominated epochs peppered by other deposit types. The magmatic arcs associated with this long-lasting margin were established on relatively thin continental or oceanic crust under epicontinental seas. Then, submarine hydrothermal activity led to the formation of VMS deposits. Eventually, the porphyry-skarn-epithermal suite formed instead, following the trail of magmatism. The occurrence of carbonate rocks in the path of the magma upflow determined the formation of skarn-related deposits, and the style and geometry of epithermal deposits. Their mineralogy and metal content was determined to a large extent by the chemistry and metal endowment of mineralising fluids (Albinson et al., 2001; Camprubí et al, 2006b; Camprubí and Albinson, 2007). The time and space distribution of magmatism and epithermal deposits in the SMO are generally coincidental, especially during the Oligocene-Miocene and around the suture zones of the Guerrero Composite Terrane and the Mesa Central. This feature suggests a prevailing deep-seated control on mineralization that links ore genesis to magmatic processes (sic, Simmons et al., 2005). The relative abundance of porphyry type deposits and the scarcity of epithermal deposits during the Paleocene does not mean that the latter did not form, though they are particularly abundant thereafter (Fig. 2). Alternatively, they could have been uplifted and subsequently eroded or covered by later rocks, especially by the thick volcanic sequence of the SMO. This is suggested by the occurrence of Eocene deposits that, like Tayoltita, are found at the bottom of deep canyons that were carved into the large volcanic pile in the central SMO.

Unlike most metallogenic provinces in the world with epithermal deposits, high sulphidation epithermal deposits are uncommon in the Mexican 'backbone'. Instead, intermediate sulphidation deposits are dominant, although most deposits have intermediate sulphidation roots or early stages and low sulphidation tops or late stages, developing different mineralisation styles upon different magmatic settings (Camprubí and Albinson, 2007). These deposits are typically polymetallic and/or Ag-rich and some are predated by skarn and/or porphyry-type ores. The ultimate reason for this particularity is, perhaps, a relatively thick crust beneath when compared to more typical settings for high sulphidation epithermal deposits in primitive arcs, as insinuated by Kesler (1997). This explanation is consistent with the (almost) exclusive occurrence of high sulphidation deposits in NW Mexico, in the 'Big Cluster' area for porphyry deposits. In this region crustal extension started during the Paleocene, and constitutes part of the southern end of the Basin and Range Province (e.g., Ferrari et al., 2005b, 2007; Simmons et al., 2005).

Additionally, the diverse topographic gradients due to large mountain ranges and the abundance of ore deposits in Mexico that are rich in dense and resistant minerals led to the formation of numerous Au, Sn, U and Ti alluvial, fluvial and coastal placers elsewhere (see the exhaustive inventory by Clark and Fitch, 2009; only a few are noted in Table 1 Electronic Supplementary Material).

The Gulf of California

The southern half of the Baja California Peninsula hosts the most important sedimentary phosphorite deposits in Mexico in the Late Oligocene-Early Miocene Monterrey Formation, which formed in a relatively shallow submarine environment (Alatorre, 1988).

The opening of the Gulf of California since the Late Miocene and its transfer from the North American to the Pacific Plate was associated with the continental extension in the SMO (Ferrari et al., 2005b, 2007) as part of the Southern Basin and Range. The ore deposits associated with this phenomenon have a distinct metallogenic 'personality'. These are Miocene to Pliocene relatively shallow syngenetic (and partly epigenetic) stratiform deposits that can be ascribed to the SEDEX type, like the Co-Cu-Zn-Mn El Boleo deposit and the Mn Lucifer deposit, that occur within the same stratigraphic section. A hydrothermal origin within a shallow submarine environment for these deposits was already indicated by Freiberg (1983). Other deposits on the western coast of the Baja California Peninsula (Fig. 2) are Mn veins and stockworks, like those on the Concepción Peninsula (e.g., El Gavilán). Moreover, in Concepción Bay there are small recent deposits and coastal hydrothermal vents that precipitate mineral associations alike those in the 'fossil' deposits (Canet et al., 2005). Both shallow and deep hydrothermal systems are widespread in the Pacific passive margin (Hein et al., 2005) and in the Gulf of California, like the Cu-Co-Zn-Ni-Au-Ag vents in the Guaymas Basin (Lonsdale et al., 1980), the Hg-Ba-Tl vents in Punta Mita (Fig. 3; Prol-Ledesma et al., 2002), and in the black Cu-Co-Pb-Ag-Cd-Mn and white barite smokers in the East Pacific Rise at the 21ºN latitude (Bischoff et al., 1983). The latter are forming in an actualistic Cyprus-type VMS setting.

In addition, there is a group of epithermal deposits in northern Baja California (e.g., San Felipe), aged Miocene to Pliocene, that formed in association with the extensional regime of the Gulf of California (Clark and Fitch, 2009) instead of arc magmatism like those in the SMO.

The Gulf of Mexico megabasin

The Gulf of Mexico opened during the Middle-Late Jurassic as a result of the breakup of Pangea (e.g., Anderson and Schmidt, 1983). Goldhammer (1999) and Padilla y Sánchez (2007) illustrated the evolution of the major basins in the region. In the resulting passive margin and horst-and-graben marginal sub-basins a thick sedimentary sequence was deposited with terrigenous, evaporitic, and carbonate facies. Today, part of the basin hosts gas fields, but also Mississippi Valley type (MVT), red-bed, SEDEX, sedimentary iron, and sulphur deposits in cap rocks of salt diapirs. The carbonate facies also host skarn deposits associated with the magmatism described in previous sections. Late Cretaceous orogenic episodes produced a significant shortening of most of the Mexican crust. The eastern front of this shortening episode is represented by the Sierra Madre Oriental fold-and-thrust belt. Orogenic deformation attenuates to the east, towards the Gulf of Mexico passive margin. The most outstanding SEDEX deposit is the giant Kimmeridgian-Early Tithonian Molango Mn deposit (Zantop, 1978), the largest manganese deposit in America.

The epigenetic and (mostly) stratabound deposit types in northeastern Mexico are MVT and red-bed deposits. These are distributed in two preferential areas, both marginal epicontinental basins, in northeastern and central Mexico (Fig. 4). The latter contains mostly fluorite deposits in hydrothermal karsts including Las Cuevas, the largest fluorite mine in the world, and the Río Verde district, as well as some celestine and strontianite deposits. The MVT province of northeastern Mexico (González-Sánchez et al., 2007, 2009) was formed in the basin that covered most of the present state of Coahuila and part of the neighbouring states. The likeliness of this region to host MVT deposits was early stated by Rosas-Solís and Sámano-Tirado (1983) when comparing the Appalachian structural features in the region with those in the USA. The northeastern basins contained horsts (paleogeographic features as paleoislands and part of the North American mainland) and grabens (main depocentres) that ruled the sedimentary regime and facies, separated by faults that later played an important role as channelways for the mineralising basinal brines and also governed the deformation styles of the Sierra Madre Oriental that led to the 'inversion' of the basin. González-Sanchez et al. (2007, 2009) catalogued over 200 deposits as MVT's in this region. The epigenetic deposits in this province show a clear mineralogical zonation that allows to determine, from south to north: (1) the Southern MVT Celestine Subprovince, associated with the Coahuila Paleoisland and the Parras Basin, (2) the Cu Subprovince, which contains red-bed Cu-(Co-Cr-Pb-Zn-U-fluorite) deposits hosted, among others, by the Las Vigas and San Marcos Formations on the southern shoulder of the La Babia Fault and on the northern shoulder of the San Marcos Fault, respectively, (3) the Central MVT Zn-Pb Subprovince, partly associated with the San Marcos Fault but also distributed in the central part of the Sabinas Basin, (4) the Central MVT Barite Subprovince, located in the central part of the basin, and (5) the Northern MVT Fluorite Subprovince, associated with the Burro-Peyotes Paleopeninsula and the La Babia Fault (Fig. 4; see also Fig. 2 in González-Sánchez et al., 2009). The Celestine Subprovince accounts for probably the greatest concentration of celestine on Earth, and the most important deposits are found in the Sierra de Alamitos and San Agustín districts onto the Coahuila Paleoisland. Other important deposits are found in Múzquiz (barite), Buenavista (fluorite), Cuatro Palmas (fluorite, and some U-rich bodies), Sierra Mojada (Zn-Pb), Reforma (Zn-Pb) in Coahuila, and Tres Marías (Zn-Pb-Ge) in Chihuahua. The Southern Cu Subprovince contains several Cu-rich deposits hosted by red beds (mostly microconglomerates, sandstones and arkoses) along the San Marcos fault, in the Cuatrociénegas area, Coahuila, and in Las Vigas, Chihuahua. These deposits are similar to those in Trans-Pecos Texas (Price et al., 1988) and may share a common 'ancestry' with them. The formation of some MVT deposits predated orogenic deformation whereas others postdated it, and occurred by means of basinal brines that were partially driven by either lithostatic pressure or orogenic compression and formed mostly stratabound deposits within

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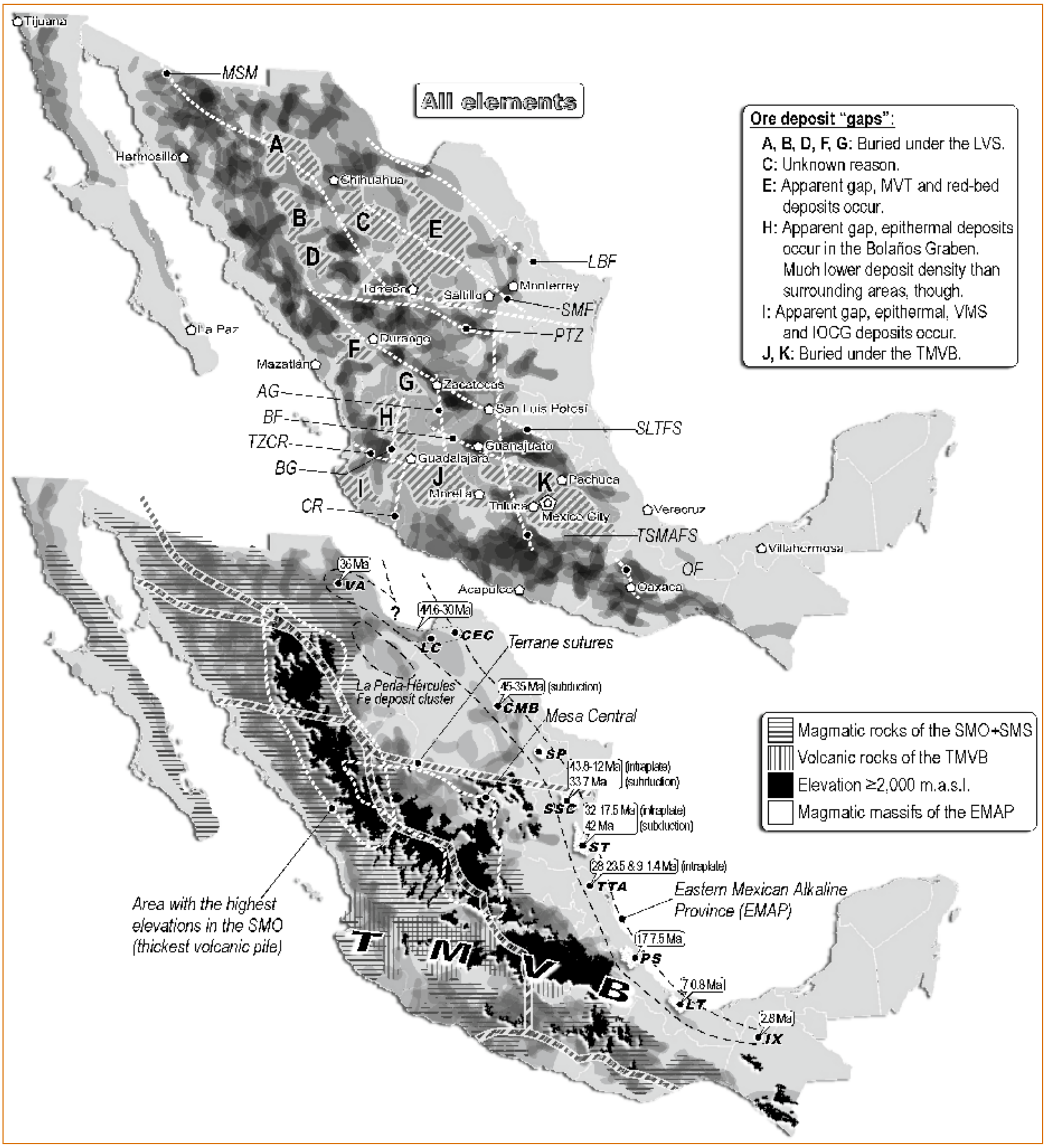

Figure 7: Above: combination of the elemental distribution for all elements as in Figure 6, with the location of the main fault zones Mexico (from Righter and Carmichael, 1992; Chávez-Cabello et al., 2005, 2007; Nieto-Samaniego et al., 2005, 2007) and the explanation for major gaps in the distribution of ore deposits. Below: same elemental distribution as above, with Cretaceous to Cenozoic magmatic rocks (from Ferrari et al., 2005b, 2007; Morán-Zenteno et al., 2005, 2007), topographic elevations ≥ 2,000 m above sea level (to give an idea of the location of the thickest volcanic piles in the SMO, SMS and TMVB; from Nieto-Samaniego et al., 2005, 2007), and the suture zones for tectonostratigraphic terranes (from Centeno-García et al., 2008). See Ferrari et al. (2005b, 2007) for a detailed structural configuration of the SMO. The ages for the magmatic complexes of the EMAP were obtained from Sewell (1968), Bloomfield and Cepeda-Dávila et al. (1973), Nelson and Gonzalez-Caver (1992), Nandigam et al. (1999), Ramírez-Fernández et al. (2000), Iriondo et al. (2003, 2004), Ferrari et al. (2005a), Molina-Garza et al. (2008), and Viera-Décida et al. (2009). Key: AG = Aguascalientes Graben; BF = Bajío Fault; BG = Bolaños Graben; CR = Colima Rift; LBF = La Babia Fault; MSM = Mojave-Sonora Megashear; PTZ = Parras Transversal Zone; SLTFS = San Luis-Tepehuanes Fault System; SMF = San Marcos Fault; TSMAFS = Taxco-San Miguel de Allende Fault System; TZCR = Tepic-Zacoalco and Chapala Rifts (structural features); EMAP = Eastern Mexican Alkaline Province; SMO = Sierra Madre Occidental; SMS = Sierra Madre del Sur; TMVB = Trans-Mexican Volcanic Belt (mountain belts); CEC = Cerro El Colorado; CMB = Candela-Monclova Belt; IX = Ixhuatán; LC = La Cueva; LT = Los Tuxtlas; PS = Palma Sola; SP = Sierra de Picachos; SSC = Sierra de San Carlos; ST = Sierra de Tamaulipas; TTA = Tlanchinol-Tantima-Álamo; VA = Villa Ahumada (igneous complexes in the EMAP).

evaporites or reefal limestones (González-Sánchez et al., 2007, 2009). The Oligocene La Coma uranium red bed-hosted (roll front) deposits occur in a similar context to the Cu Subprovince although their formation was probably diachronic.

The „trouble" ores

The deposits that are not what they may seem or what they were first described, plus those not well understood yet, are tagged here as 'trouble ores'. In previous sections and Table 1 (ESM) several deposits are branded with type denominations, beyond the discussion that led to such labeling or the criteria for classification that have been used in this paper. It is not a trivial question, as some economically important deposits were ascribed to vaguely reasonable types or using scant evidence. Although their genesis is not fully explained so far, deposition models changed for (1) the Devonian stratiform barite deposits of Sonora from SEDEX (Arreola, 1978) to cold methane seepage (Torres et al., 2003, 2004) and back to SEDEX (Emsbo and Johnson, 2004; Johnson et al., 2009), (2) the Peña Colorada iron deposit from skarn (Zürcher et al., 2001) or SEDEX (Rivas-Sanchez et al., 2006) to IOCG (Tritlla et al., 2003; Camprubí and Canet, 2009), (3) the San Fernando Cu-Au deposit from porphyry-type (Staude and Barton, 2001) to IOCG (Lopez et al., 2005; Cruise et al., 2008), (4) the Francisco I. Madero polymetallic deposit from SEDEX (Yta et al., 2003) to skarn (Canet et al., 2009), and (5) the Las Cuevas, Buenavista and fluorite deposits in the Río Verde district from skarn (Ruiz et al., 1980) to MVT (González-Partida et al., 2003; Levresse et al., 2003), although Kemiac and Cookson (1975) early postulated a 'hydrothermal karst' model for the Río Verde deposits. The origin of other deposits remains disputed: the La Azul fluorite deposit in Taxco is considered epithermal by Pi et al. (2005, 2006) and MVT by Tritlla and Levresse (2006).

On the other hand, many deposits lack proper or conveniently published studies. Such is the case of the iron deposits in southern Mexico that extend into the Tehuantepec Isthmus (Zaniza, Ixtlayutla, La Ventosa, Totolapilla, Niltepec, Tepanatepec, El Carmen, etc.). Most of them are characterised as small skarns or replacement bodies (Ojeda-Rivera et al., 1965), and little is known about them. It is suggested that they may form an IOCG belt along with the deposits in Colima, Jalisco and Michoacán, provided that the Zaniza deposit formed synchronically and shares many geologic characteristics with them. However, the 'IOCG issue' is going to linger for a while, as this group of deposit types is globally (and locally) not well understood or accepted. However, many iron deposits in Mexico have been described for decades as 'volcanogenic' (vg. Cerro de Mercado, La Perla, Peña Colorada, Las Truchas, La Guayabera, La Colomera, El Encino, Hércules, and Mochitlán; Pesquera et al, 1977) or 'Kiruna type' (Klemic, 1970), and they cannot be dismissed as classic skarns whether they are 'skarn look-alikes' or not. A possible extension northwards of the IOCG belt is represented by a few Fe-Au-Cu deposits in Sinaloa (Bustamante and Soberanes, 1978) and Fe-Cu deposits in the Baja California Peninsula (Clark and Fitch, 2009), that were described as IOCG deposits by Lopez et al. (2005) and Cruise et al. (2008). Interestingly, all these deposits constitute the closest ore belt to the paleotrench (Clark et al., 1979; Damon et al., 1981a), and their ages roughly decrease from north to south (Paleocene-Oligocene to Miocene). The knowledge about this ill-defined belt would greatly benefit from determining the ages and tectonic setting of the deposits in the 'Pacific Sierras Madre'.

Also, there are many carbonate- and evaporite-hosted epigenetic low-temperature Hg and Sb deposits in Oaxaca, Guerrero, Querétaro, San Luis Potosí, Zacatecas and Durango, of undifferentiated Tertiary age and undisclosed type (Mixtepec, Huitzuco, Huahuaxtla, Chonextla, Apatzingán, Tzitzio, Soyatal, Guaxcama, Wadley, etc.). Both Huitzuco and Guaxcama are evaporite-hosted deposits. Huitzuco is a Hg deposit associated with vertical tubes carved in Albian-Aptian evaporites, interpreted by Vaupell (1938) as due to geysers. Both the Huitzuco (evaporite-hosted) and Huahuaxtla (carbonate-hosted) deposits are found in the fault zone that limits the southwestern flank of the resurgence block of the Tilzapotla caldera (Morán-Zenteno et al., 2004). Thus it is likely that the formation of these deposits is associated with 'epithermal' stages driven by the caldera activity. Guaxcama is a sulphur deposit with associated small cinnabar showings; González-Reyna (1956) described common features between this deposit, Huitzuco and Huahuaxtla, and suggested a hydrothermal origin related with an igneous source, although only informal studies have been conducted in the area. Early descriptions (i.e., Archibald, 1950) of the deposits at Wadley, while mining in the area peaked, emphasise that the emplacement of Sb mantos is systematically controlled by faulting. All authors henceforth described these deposits as carbonate-hosted shallow epithermal, congruently with the general structurally controlled intrusion-centered skarn/epithermal setting of the Sierra de Catorce area. In other mineralised areas in the Catorce region, very similar deposits have been described in the same fashion (Flores-Aguillón, 1992). All the same, Tritlla et al. (2008) apparently advocate a MVT model (so far, unsustained) or, in their words, "related with the upflow of (...) basinal brines that interacted with evaporitic horizons. Dissolution coupled with TSR-like reactions would account for (...) ore precipitation". Despite the historical good geological and mineralogical descriptions for the Mexican Hg and Sb deposits published by the Mexican Geological Survey, no physicochemical data were ever obtained on mineralising fluids nor mechanisms for ore deposition were determined. Thus, feasible deposit types cannot be easily invoked to describe them yet. Some Hg deposits are associated with Sn veins in rhyolites (Sierra de Chapultepec, Guadalcázar), but it has been speculated that most Hg and Sb deposits are shallow epithermal or even MVT deposits. However, no revealing data has been published to date. Hg and Sb deposits are strongly and unsurprisingly tied in time and space (Fig. 5), thus suggesting their affinity also in terms of deposit types. Further research must shed some light on the presently ill-defined genesis and timing of many ore deposits in Mexico.

Another interesting aspect for further research is the possible genetic link between epithermal deposits and Sn deposits in topaz rhyolites, provided that both types occur in some areas in the SMO within the same time range (they occur together in the Sombrerete, Avino and Guadalcázar districts). In this sense, Burt et al. (1982) proposed a suite of deposit types due to the magmatism associated with topaz rhyolites, including porphyry, greisen or pegmatite mineralisations underneath. F-rich topaz rhyolites are likely to be the extrusive equivalent of aluminous anorogenic granites, and Sn would have been entrained in the vapour phase after the eruption of rhyolites along with other incompatible fluorophile-lithophile elements like U, Be, Li, Th, Mo, and perhaps, W, Nb and Ta (Christiansen et al., 1983). Sn-rich polymetallic epithermal deposits are common in geologic settings alike those in Mexico, typically in Perú and Bolivia (e.g., Cerro de Pasco; Baumgartner et al., 2008). The Andean deposits may be associated with moderate to high magmatic fractionation processes (Dietrich et al., 2000), and rhyolite-bearing tin deposits in Mexico may have formed as extreme differentiates in shallow magma chambers (Huspeni et al., 1984). Alternatively, they may be the result of partial melting after the passage of hot mafic magmas under an extensional tectonic setting allowing those small batches of magma to rise relatively unscathed to the surface (Christiansen et al., 1983). In fact, topaz rhyolites were emplaced in central Mexico due to extensional tectonics during the Oligocene (Orozco-Esquivel et al., 2002). Presently, the continental crust beneath the Mesa Central is significantly thinner and topographically higher than in the surrounding Sierra Madre Occidental and Sierra Madre Oriental, and is undergoing partial melting (Nieto-Samaniego et al., 2005, 2007). Tuta et al. (1988) inferred a thick crust in the area during the Oligocene, but its actual configuration and thickness is not well understood and might have been more complex than simply 'thick' or 'thin' (Á.F. Nieto-Samaniego, written communication, 2009).

The role of the basement vs. magmatism and structural control

Much has been said about the influence of the Guerrero Composite Terrane on the chemistry of ore deposits and mineralising fluids. It has been suggested that the abundance of ore deposits in western Mexico is due to the 'fertility' of the basement, to the point that the Mesozoic VMS deposits would have been pre-concentrations for Cenozoic deposits (e.g., de Cserna, 1971). Such hypothesis lingers in several recent geological-mining maps edited by the Mexican Geological Survey. In general, that explanation seems unlikely because (1) the distribution of Mesozoic VMS deposits is relatively limited (they are essentially restricted to the southern portion of the Guerrero Composite Terrane) when compared to widespread Cenozoic deposits (Fig. 2), (2) the distribution of Cenozoic deposits follows only the distribution of Cenozoic magmatism (as noticed by Damon et al., 1981a; Clark et al., 1982) and the availability of fracture zones, regardless of the occurrence of different terranes or types of basement, and (3) the available geochemical data for Cenozoic deposits (O, H, He isotopes and volatile composition in fluid inclusions; e.g., Albinson et al, 2001; Camprubí et al., 2006b; Camprubí and Albinson, 2007) suggest the occurrence of multiple sources for mineralising fluids but also that metal-carrying hydrothermal pulses for epithermal deposits were so endowed due to their magmatic (juvenile?) character. Also, sulphur isotope data shows both sedimentary/metasedimentary and magmatic sources for the necessary sulphur as a metal ligand and, in general, the relative amount of H_2S in solution correlates positively with the proportion of magmatic fluids in mineralising brines inferred from N_2/Ar ratios. In the Sierra Madre del Sur, the Taxco, Tilzapotla and Huautla volcanic centres (~38 to ~32 Ma), with associated important epithermal and skarn deposits, display isotopic data that suggest the occurrence of an episode with a significant contribution of mantle wedge-derived mafic magmas with variable degrees of crustal contamination from a relatively homogeneous lower crust (Morán-Zenteno et al., 2003). Although this does not allow to ascertain any direct implication in the nature of mineralising fluids in epithermal deposits, their isotopic and volatile geochemistry, the relatively short time span between their formation and the preceding volcanism (e.g., Camprubí et al., 2003, 2006b; Valencia et al., 2005, 2008; Camprubí and Albinson, 2007), as well as their common time and space distribution, suggest that the magmatic connection of epithermal deposits in Mexico may be tighter than previously noticed.

On the matter of tectonostratigraphic terranes, their control on the emplacement of ore deposits appears to be restricted to the combination of magmatism and the presence of terrane suture zones (Fig. 2). That is, the 'invasion' by magmatism of areas that were already structurally weak or that experienced long-lasting faulting made excellent channelways for the upflow of both magmas and mineralising fluids, as suggested by Miranda-Gasca (2000) and Nieto-Samaniego et al. (2005, 2007). The large quantity of ore deposits and the virtually exclusive occurrence of Sn veins in topaz rhyolites that concentrate on the southern border of the Mesa Central (the San Luis-Tepehuanes Fault System) and the suture zone of the Guerrero Composite Terrane (Fig. 2) supports this interpretation. However, that was possible during the Oligocene, at the peak of the geographic extension and intensity of magmatism in the SMO, but when magmatism retreated to southwestern Mexico during the Early Miocene and the main terrane suture and fault zones were out of the reach of magmatism, ore-forming processes concentrated in other regions.

Metallogenic epochs

Epithermal, skarn, porphyry, VMS, IOCG, and volcanogenic tin and uranium deposits overlap in time and space during the Cenozoic and the Mesozoic (Fig. 5), and also overlap partially in a similar fashion with deposits associated with mafic-ultramafic complexes. Other types of deposits, genetically unrelated to magmatism, such as orogenic gold (associated with the Laramide orogeny), SEDEX, phosphorites, MVT, and red-bed deposits (associated with sedimentation and basin dynamics in epicontinental environments), do not share similar time and space patterns with the above types, as expected. The time distribution of ore deposits in Mexico leans heavily on the Cenozoic (Fig. 5). Clark and Fitch (2009) determined six preferential time intervals in the metallogenic history of the region: Proterozoic, Paleozoic, Permo-Triassic, Jurassic to Early Cretaceous, Late Cretaceous to Early Miocene, and Late Miocene to Present. To this paper's reckoning, such epochs are congruent with the compilation of available ages (Table 1, ESM). However, the relative scarcity of pre-Cenozoic deposits and the meager amount of dated deposits makes difficult to draw any general explanation for such deposits, other than those already stated in previous sections of this article. During the Cenozoic, nonetheless, the age distribution of ore deposits describes several peaks (no less than eleven) and valleys. Based on the time and space distribution of ore deposits, and on the dominant types, two time-space slices can be determined for the Mesozoic and five for the Cenozoic: (1) Middle Jurassic to Early Cretaceous in SW Mexico, mostly VMS deposits, (2) Cretaceous in the SW and Pacific areas, mostly deposits associated with mafic-ultramafic rocks, (3) Paleocene to Early Eocene in the NW and Pacific areas, dominantly porphyry-type deposits, also IOCG and increasing amount of skarns with time, (4) Early to Late Eocene in NW and central Mexico, dominantly skarn and epithermal deposits, (5) Oligocene virtually everywhere, dominantly epithermal deposits, Sn veins and greisen (in the southern portion of the Mesa Central) and some skarns, (6) terminal Oligocene to Early Miocene in SW and central Mexico, dominantly epithermal, and (7) Middle Miocene to Present everywhere, containing several deposit types. Most types of deposits and the vast majority of dated deposits are genetically associated with magmatism of different kinds, emplaced at different crustal levels. Hence, it is no surprise that they mimic the time and space distribution of magmatism.

Metal associations and their space distribution

The element maps (Fig. 6) obtained by Fabregat-Guinchard and Cortés-Guzmán (1978) are based on the analysis of all the known ore deposits in Mexico at that time, although the maps contain only economically productive deposits. Their combinations in characteristic metal associations show features that need to be further explored at a greater detail. The associations that have been initially considered here are Ag-Au (mostly epithermal), Ag-Pb-

Zn (epithermal, skarn, VMS), Au-Cu (porphyry, high sulphidation epithermal), Fe-Cu (skarn, IOCG), Hg-Sb (shallow hydrothermal), Ag-Au-Pb-Zn-Cu (several types of deposits). Also, Sn deposits may have some genetic affinity with Hg and Sb deposits, as they share a common distribution in central Mexico. Alternatively, their affinity may not be genetic as much as it may be due to sharing the same crustal environment. All the metals in the established metal associations show a good correlation. Au correlates well with Cu and Ag elsewhere, and so does Ag with Pb and Zn. Cu deposits are particularly abundant in southwestern Mexico, where the correlation between Cu and Au is the weakest. That is explained by the close association of Cu with Fe in iron deposits (IOCG clan and similar deposits). Such interpretation is favoured by the discrete distribution of Fe in only a few regions.

If we put together the geographical distribution of all analysed elements, the resulting features should display different levels of 'general prospectiveness' in space. As expected, the most prospective areas are the western and eastern parts of the Sierra Madre Occidental (SMO), the area around the Mesa Central, and the Sierra Madre del Sur (Fig. 7). However, that distribution leaves several gaps. Most gaps are apparent because there are known important deposits in those areas or the possible deposits are buried under large piles of volcanic rocks in the SMO or the Trans-Mexican Volcanic Belt. The thickest pile of volcanic rocks in the SMO (Fig. 7) determines the curiously straight end of the area with abundant deposits in the western SMO (see Ag-Au and Au-Cu distribution in Fig. 6). Other areas (C, G and H in Fig. 7) are dubious because they contain vast exposures of the SMO magmatism and are not buried under large piles of volcanic rocks. Thus, following the general scheme of ore deposits in the region, these areas 'should' have relevant ore deposits. The area H contains important Miocene epithermal deposits in the Bolaños Graben but, intriguingly, areas G and H have scarce deposits, especially because they experienced virtually non-stop volcanism from the Eocene to the Miocene, during the most metallogenically productive epochs in Mexico. Compared with neighbouring areas like the southern portion of the Mesa Central or the southernmost end of the SMO (see also Fig. 2), ore deposits are very scarce in areas G and H. Moreover, if we look back to typical metal associations in Fig. 6, a large gap devoid of relevant ore deposits occurs in areas G, H and J, which apparently contain only F and Sn deposits. The relative scarcity of ore deposits in this region and the apparent lack of ore deposits with the most common metal associations are features that cannot be satisfactorily explained so far.

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INIRM). Although none of them is cited here, as a most valuable support to his research, the author used no less than forty 1:250,000 and 1:50,000 maps edited by the Mexican Geological Survey (available at http://www.sgm.gob.mx). Dante Morán, Elena Centeno, Carles Canet, Ángel Nieto, Tawn Albinson, Rosa M. Prol, Eduardo González-Partida, and M. Guadalupe Villaseñor provided data and ideas that helped to greatly improve this paper, though noone must be held responsible for its content but the author. Also, Massimo Chiaradia is thanked for (nicely) challenging the author to write it. Collecting information for this paper, especially from out-of-print publications or relatively obscure sources, was facilitated by the personal archives and documentary wealth left by the late Ernesto López-Ramos and Francisco Fabregat.

References

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GAC/MAC Annual Meeting. Ottawa, Canada. Web-site: http://www.gac.ca/ANNMEET/annmeet.html

*__September__
11th BIENNIAL SGA MEETING, Antofagasta, Chile - Dr. Eduardo Campos, Departamento de Ciencias Geológicas, Universidad Católica del Norte, Antofagasta, Chile; e-mail: edcampos@ucn.cl; Web-site: http://www.e-sga.org

***September 18-23**
SOCIETY OF EXPLORATION GEOPHYSISTS (SEG) , San Antonio, Texas, USA. Web-site: http://www.seg.org/meetings/; E-mail: meetings@seg.org

October 9-12
GEOLOGICAL SOCIETY OF AMERICA: 123rd Annual Meeting. Minneapolis, Minnesota, USA. GSA Meetings Department, P.O. Box 9140, Boulder, CO 80301-9140, USA. Phone +1 303 447 2020, Fax: +1 303 447 0648, E-mail meetings@geosociety.org, http://www.geosociety.org/meetings/index.htm

2012

***August 5-15**
34th INTERNATIONAL GEOLOGICAL CONGRESS (IGC 2012, Australia). Brisbane, Australia. E-mail Ian.Lambert@ga.gov.au; web-site: www.ga.gov.au/igc2012

News from the Prague Student Chapter

Aneta Stastna, *Vice-President SGA Student Chapter, Charles University, Prague*
Jakub Trubač *President SGA Student Chapter, Charles University, Prague*
Lukáš Vondrovic, *Member and Treasurer SGA Student Chapter, Charles University, Prague*

In the early spring 2009, on 4-5 March, the SGA Student Chapter in Prague organized an exciting two-day fieldtrip to Moravia to visit the MND Group, which represents the largest company specialized in exploration and extraction of crude oil and natural gas in the Czech Republic.

The first day we visited the field base of 2D seismic measurements in Hustopeče (south Moravia) where seismic data were gathered and partly analysed by means of the data processing (convolution and deconvolution processes). After a short lecture relating to the local geological setting, the 2D seismic measuring system and the data evaluation we started the field trip. The trace area around the central control station (the recording truck) was unfortunately affected by strong wind so that the seismic measurement was not possible just at that moment. Self seismic measurement was performed with the help of four seismic vibrators which are truck-mounted devices capable of injecting low-frequency vibrations of 8 to 120 Hz into the earth and are moving between a 30 m range. The vibroseis represents one of a number of seismic sources used in reflection seismology. From the entire measured signal only 30% is efficient, the rest of the signal being locally disturbed by the Quaternary layers. The signal reaches a system of geophone groups and the information from each geophone must be transmitted via long and heavy cables to the recording truck.

The Uhřice oil deposit and gas storage was our second stop of the excursion. This accumulation belongs geologically to the southeastern slope of the Bohemian Massif. Generally the most important accumulations occur particularly in collector strata of the Miocene and Jurassic and jointed and weathered portions of crystalline rocks. Light, sulphur free, paraffin to paraffin-naphthene oil prevails in this field. We were informed about local oil mining technology, the borehole drilling method and the geological documentation of the oil well in detail.

After this exciting field trip we moved to the central office of MND Group in Hodonín. We could see the fully equipped and certified chemical laboratories where the quality of oils, gases, rocks and water is tested. Among others we became acquainted with spectroscopic, photometric and chromatographic methods. We were impressed by the petrographic description of rocks rich in hydrocarbons which exhibit various (mainly yellowish-gold) luminescences under the UV lamp. The evening was completed by a short lecture about the geological situation of the studied area rich in crude oil and natural gas (i.e., slopes of the Bohemian Massif, Ždánice Unit and Vienna Basin).

The second day continued with lectures and presentations in Hodonín and then in Brno. Employees of the MND Group gave a talk on the geophysical borehole logging, the internal database and the method of reserve calculation. We previewed the Schlumberger owned PC software, called Petrel, for a complete imaging and interpretation of seismic data. Oil deposit traps were more easily distinguishable by means of the seismic modelling in 3D. We finished our excursion in the department of seismic processing in Brno. Rough seismic data are processed there by means of latest computational procedures.

Our SGA Student Chapter would like to invite all interested students to attend our meetings. For more information about us, please visit our web page: http://sga.cuni.cz. We look forward to meeting and greeting you.

2D seismic measurement by the help of four seismic vibrators near Němčice, Czech Republic.

Report on the XXVIII UNESCO-SEG-SGA Latin American Metallogeny Course, in Belo Horizonte, Brazil, 19-26 May, 2009

Fernando Tornos, International coordinator of the 2008 edition

Instituto Geológico y Minero de España, 37001 Salamanca (Spain), e-mail: f.tornos@igme.es

The last edition of the UNESCO-SEG-SGA Course on Metallogeny has been hosted by the CDTN-CNEN (Centro de Desenvolvimento Tecnologia Nuclear - Comissão Nacional de Energia Nuclear, Brasil), in Belo Horizonte, Brazil and was organized by Francisco Javier Rios as regional academic coordinator and Fernando Tornos as his international partner. The field trip of this course was planned and led by Javier (CDTN) and Carlos Rosiere as well as Lydia Lobato from the CPMTC-UFMG, Brazil. For the organizers, this has been a big gamble since it has been the first time that we have jumped from a Spanish speaking country to a Portuguese speaking one. Also, geology in Brazil is dramatically different from that of previous editions of the course, with an old cratonic basement that strongly contrasts with the „young" Andean volcanic arc that we were used to in th eprevious editions.

However, Javier and his great team (Sonia, Tatiana, Lucilia, and Ana Rosa) sorted out all possible problems, made life easy to all of us and organized a fantastic course. The theoretical part included talks on radiogenic geochemistry and isotope dating (Fernando Barra, University of Arizona, Tucson, USA), orogenic gold and iron deposits (Steffen Hagemann, ET, University of Western Australia), fluid inclusion analysis and the transport of Cu-Au in magmatic-hydrothermal systems (Christoph A. Heinrich (ETH Zurich, Switzerland), gold deposits in Brazil and the Quadrilatero Ferrifero

The speakers of the course.

(Lydia Lobato, Universidade Federal de Minas Gerais, Brasil), iron deposits (Carlos Alberto Rosiére, Universidade Federal de Minas Gerais, Brasil), geochemistry of ore deposits and IOCG-like deposits (Fernando Tornos, Instituto Geológico y Minero de España, Spain), gold deposits in Carajas (Raimundo Netuno Nobre Villas, Universidade Federal do Pará, Brasil) and fluids in IOCG systems (Prof. Dr. Roberto Perez Xavier, UNICAMP-Universidade de Campinas, Brasil). It was complemented by an afternoon short practical course on electron microprobe, fluid inclusions and geochemistry. This theoretical part was attended by about 70 scientists, M.Sc. and Ph.D. students, professors and geologists belonging to different mining companies and coming from Brazil, Colombia, Argentina and Peru. It is worth to note that the course hosts more and more people coming from the industry and that most of them are really interested in what in South America have been traditionally considered as academic disciplines, such as theoretical geochemistry, fluid inclusion studies or isotopic dating.

One of the most fascinating aspects of the course was communication. Talks were presented in Spanish, Portuguese and English, with imaginative answers in those languages and many of them in portuñol (a mixture of Portuguese and Spanish). Here we would like to acknowledge the big effort done by speakers and attendants in order to solve the barrier problem. This reached its maximum during the after work. If all the courses have been great, Brazil will pass to the history of these courses as one of the most vivid nightlife, all of them organized and encouraged by our Brazilian colleagues. That included dinners, wine tasting parties and long nights of dancing.

The practical course included visits to some of the most prominent deposits of the Quadrilatero Ferrifero, including the famous Itabira iron mine as well as the orogenic gold deposits of Corrego do Sitio and Lamego and the iron mine of Samarco. They were complemented with the visit to the famous outcrop of itabirite of the Sierra da Piedade and some prospects of Au-U in conglomerate that are strikingly similar to the Witwatersrand. All the speakers accompanied the field trip. Nights were at the natural reserve of Sierra de Caraça and the World Heritage City of Ouro Preto, one of the most prominent mining cities of the world.

As previous editions, the course could not be held without the collaboration of international and local institutions. The attendance of students and some professors was possible due to the economic support of UNESCO, SEG and SGA while the general costs were covered with the generous contribution of the CDTN and the Government of Minas Gerais as well as Ministerio de Minas e Energia of Brazil, Anglo Gold Ashanti, Votorantim, Vale, Anglo American, Ferrous, Terra Ativa, and other institutions and companies.

The next course will be held in Concepción (Chile) and organized by Bernhard Dold, and will be devoted to the environmental aspects of mining. The 2011 edition will be probably held in Colombia and coordinated by Juan Carlos Molano (University of Bogotá) and Fernando Barra.

More information on the course can be found in http://www.unige.ch/sciences/terre/mineral/seminars/belo_horizonte09/belo_horizonte09.html

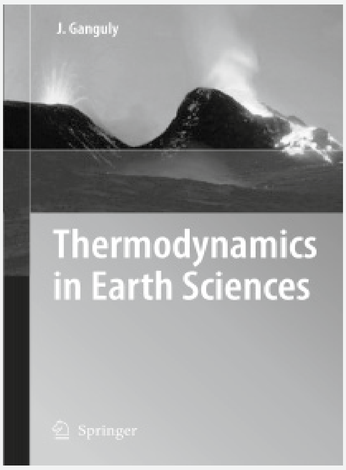
Group photo of the 28 Latin American Course of Metallogeny held in Belo Horizonte.

As always, the auditorium was full of attendants coming from all Latinamerica.

Lydia Lobato explaing the pecularities of the orogenic gold deposits at Lamego.

At the Sierra da Piedade outcrop of itabirite.

Explanation on the geology of the Corrego do Sitio mine.


J. Ganguly
Thermodynamics in Earth Sciences
Springer

SGA

Society for Geology Applied to Mineral Deposits (www.e-sga.org)

MEMBERSHIP APPLICATION FORM

I would like to become a member of the **Society for Geology Applied to Mineral Deposits** and to receive my personal copy of **Mineralium Deposita**. Membership fees will be due after acceptance of the membership application by the SGA Council.

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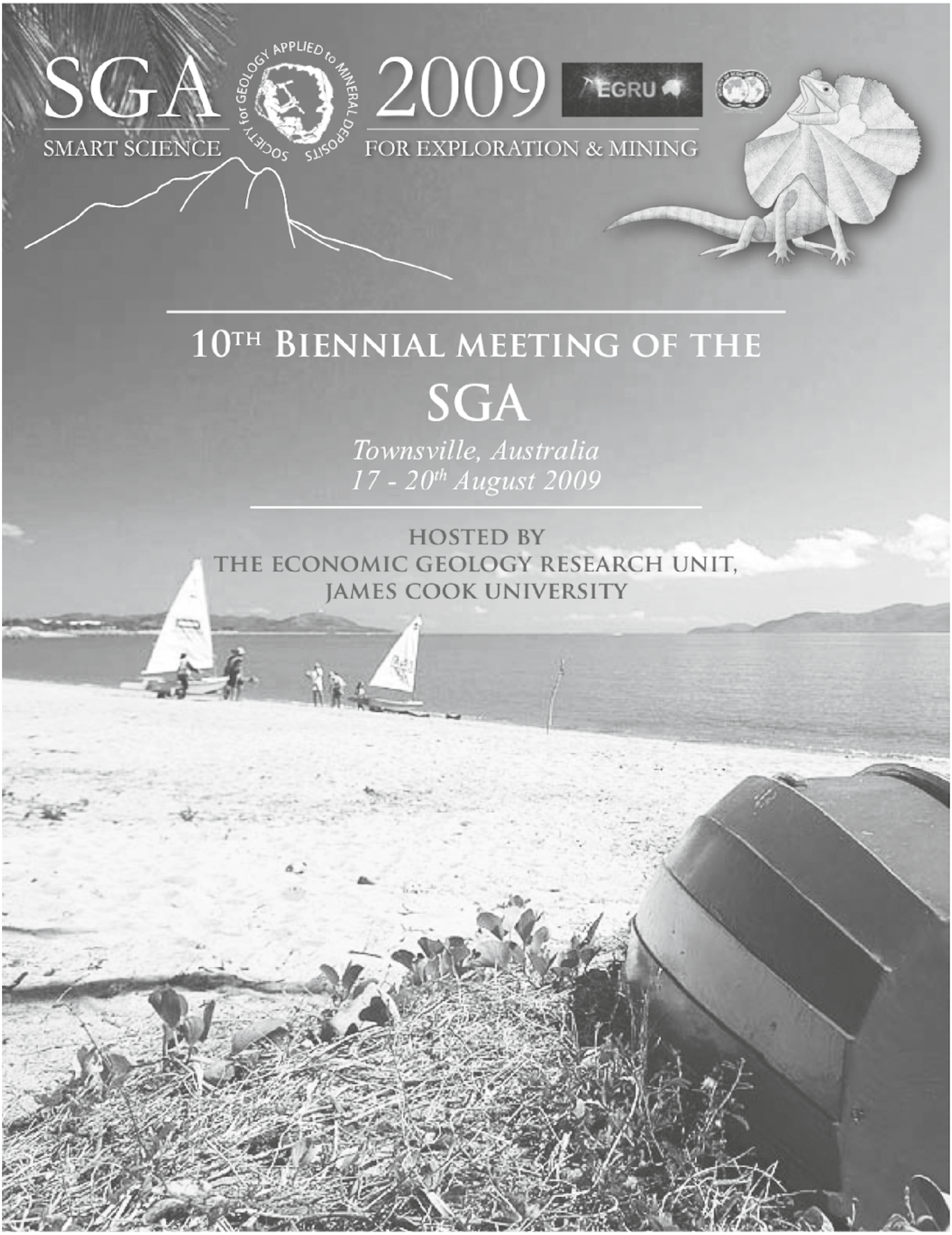
Send the Membership Application Form to:

Dr. Jan Pasava
SGA Executive Secretary
Czech Geological Survey
Klárov 131/3
CZ-118 21 Praha 1
CZECH REPUBLIC

Phone: ++(420)-2-51085506
Fax: ++(420)-2-51818748
E-mail: secretary@e-sga.org


SGA 2009
SOCIETY for GEOLOGY APPLIED to MINERAL DEPOSITS
EGRU
SMART SCIENCE FOR EXPLORATION & MINING
10TH BIENNIAL MEETING OF THE
SGA
Townsville, Australia
17 - 20th August 2009
HOSTED BY
THE ECONOMIC GEOLOGY RESEARCH UNIT,
JAMES COOK UNIVERSITY

SGA 2009 SMART SCIENCE FOR EXPLORATION & MINING

The Society for Geology Applied to Mineral Deposits (SGA) and the Economic Geology Research Unit (EGRU) at James Cook University, in association with the Society of Economic Geologists (SEG), are delighted to invite all their members and others interested in economic geology to the

10TH BIENNIAL MEETING OF THE SGA

Townsville, Australia

17 - 20th August 2009

THE TOWNSVILLE ENTERTAINMENT & CONVENTION CENTRE
AND JUPITERS HOTEL & CASINO
TOWNSVILLE QUEENSLAND, AUSTRALIA

PROGRAM

Thematic Sessions

(A) Ore-Forming Processes

1. Mineral systems and large-scale exploration targeting
Paul Roberts (CSIRO), Cam McCuaig (CET),
James Cleverley (CSIRO)

2. Magmatic ores and their petrogenetic/tectonic setting
Steve Beresford (CET), John Mavrogenes (ANU),
Marco Fiorentini (CET)

3. Hydrothermal processes in ore-forming systems
Tony Christie (IGNS), Poul Embso (USGS)

4. Dating ore deposits: geological and geochronological problems
Massimo Chiradia (Uni. Geneve), Ken Hickey (UBC)

5. Metal remobilization in the formation of hypogene and supergene ore deposits
Gregor Borg (Uni. Halle), Paulo Vasconcelos (UQ)

(B) Specific Mineral Systems

1. Golden controversies: classification of epigenetic gold deposits
Craig Hart (UBC), John Miller (CET)

2. Sediment- and volcanic-hosted Cu, Cu-Zn and Pb-Zn deposits
Rod Allen (LUT), Jan Peter (GSC), Stuart Bull (CODES)

3. Understanding porphyry-epithermal transition
Robert Moritz (Uni. Geneve), Eduardo Campos (UCN Chile)

4. The origin of enriched iron and manganese ore deposits
Steffen Hageman (UWA), Carlos Rosiere (UFMG),
Thomas Angerer (CET)

5. The nature and origin of uranium deposits
Frank Bierlein (AFMECO), Christian Marignac (Uni. Nancy)

6. Genesis of iron oxide-copper-gold deposits
Mike Porter (Portergeo), Fernando Tornos (IGME),
Louise Corriveau (GSC)

7. Diamonds: Where are they and why?
Simon Richards(JCU), Bernd Lehmann (Tech. Uni. Clausthal)

(C) New and Frontier Areas

1. Applied mineralogy (metallurgy, exploration, environmental management and remediation)
Steve Walters (CODES), Julie Hunt (CODES),
Joel Brugger (SA Museum)

2. Non traditional geochemical and microchemical methods: applications in ore genesis and exploration
Sarah Gleeson (Uni Alberta), Bin Fu (Uni. Melb.)

3. Mining and the environment: issues and solutions
Bernd Lottermoser (JCU), Dave Craw (Uni. Otago)

4. Finding resources under cover: new geophysical and imaging techniques for exploration
David Giles (U Adelaide), Mark Gettings (USGS)

5. Structual controls on mineralization, conceptual targeting and prospectivity/endowment analysis
Tom Blenkinsop (JCU), Oliver Kreuzer (Regalpoint Exploration), Alok Porwal (CET)

6. Numerical simulations of hydrothermal systems
John McLellan (JCU), Philipp Weis (ETH Zurich)

7. Three dimensional modelling: development and application of 3D geomodelling in mining and mineral exploration
Leonardo Feltrin (JCU), Laurant Allieres (Monash Uni)

8. Tectonic analysis and history of terrains as indicators of metallogenic fertility
Par Wiehed (LUT), Richard Blewett (GA)

(D) General Session

New developments in mineral deposits geology
Pat Williams (JCU)

SEG Special Session

New discoveries: the geology of new mineral deposits
Tim Baker (Sovereign Metals), Neil Adshead (Passport Capital Corp.)

David Groves, *SGA President*
'What is special about giant mineral systems'

SGA Plenary Session

Self-organized systems, ore formation and mineral system science .... Jon Hronsky
Fluid inclusions and numerical modelling of magmatic-hydrothermal systems .... Chris Heinrich
Precious Paradigms: controversies in PGE ore genesis. .... Jim Mungall
Lithospheric analysis and mineral systems .... Sue O'Reilly
Metallogenic evolution with time .... Rich Goldfarb
Mesozonal mineralization in the making .... Rick Sibson
Magma fertility and mineralization .... David Cooke

SEG Plenary Session

Outlook for the mining industry for the next 5 years .... John Thompson
New advances in exploration techniques applied to uranium and IOCG's .... Rick Valenta
Gold solubility, transport and deposition in active epithermal systems .... Stuart Simmons
IOCG's, porphyries and alkali alteration in the American Cordilleras .... Mark Barton

Workshops and Short Courses

1. Ore Textures and Breccias
2. 2D/3D Mineral Prospectivity & Geological Process Modelling
3. Sediment-Hosted Gold: Carlin & Orogenic Styles
4. Porphyry Copper & Epithermal Gold Deposits
5. The Nature & Genesis of Uranium Deposits in Australia, Canada & Worldwide: insights from the new & improved geological tools/technology
6. Fluids Minerals & Melts: investigating hydrothermal processes using laser ablation-ICPMS techniques.
7. Hyperspectral imaging: applications to exploration
8. Iron-Oxide Copper Gold-Deposits; geology & discovery
9. Mineral Systems: concepts to practical outcomes

Field Trips

1. Nonsulfide Zinc Ore Deposit of Angouran in NW Iran
2. North Queensland Gold Deposits
3. High Grade BIF iron deposits: a Yilgarn-Hamersley comparison
4. Architectural Controls on a 2.6 to 2.7 World Class Gold-Nickel camp, Kambalda,Western Australia
5. Olympic Dam-Mt Painter Cu-Au-U, South Australia
6. Breccias, Fluids & Copper Mineralization in the Mt Isa & Cloncurry Region NW Queensland
7. Apatite-Magnetite Ore Deposits of the Bafq Region in Central Iran
8. West Coast, South Island New Zealand: Gold and Coal
9. Active and Extinct Epithermal Environments of the North Island New Zealand

Registration Fees AUD & inclusive of GST	**Early Bird** (before 31/05/09)	**Late** (after 31/05/09)
Member SGA, EGRU, SEG	$ 825.00	$ 935.00
Non-Member	$ 935.00	$1045.00
Student Member SGA & SEG	$ 375.00	$ 425.00
Student Member SGA or SEG	$ 400.00	$ 450.00
Student Non-Member	$ 450.00	$ 500.00
2 Days Only	$ 660.00	$ 715.00
Accompanying Person	$ 110.00	$ 110.00

SGA 2009
SMART SCIENCE FOR EXPLORATION & MINING

Students

Attractive incentives are being offered to students to encourage their participation in SGA 2009. These incentives include:

- Discounted registration fees
- Industry sponsored student event
- Student poster session
- Sponsorship packages for field trips, workshops or travel costs
- $1000.00AUD cash prize will be presented for the best student presentation or poster

An application form for student sponsorship is available at http://sga2009.jcu.edu.au

Sponsorship and Exhibitor Packages

On behalf of the Organising Committee, we invite you to consider one of our sponsorship packages available at the 10th Biennial meeting of the SGA. We have a strong and specific commitment to ensure the best possible outcomes regarding booth placement and visibility, specific sponsoring organisation benefits including branding, advertising and registration subsidies, and the coordination of social activities

Full details of the Sponsorship and Exhibitor Packages can be viewed at http://sga2009.jcu.edu.au.

Student Sponsorship

Sponsorship support for students to attend the SGA Meeting is being sought to encourage as many students as possible to attend. Various levels of student sponsorship are available. Please see the website for full details http://sga2009.jcu.edu.au

KEY DATES	
January 2009	**Registration opens**
16 January 2009	Submission of abstracts available via website
16 February 2009	Abstract submission deadline
16 February 2009	Applications close for student support
16 March 2009	Editorial decisions from convenors
30 April 2009	Final revised abstracts from authors due
24 May 2009	Notification of final acceptance or rejection of abstract
31 May 2009	Deadline for early bird registration
31 May 2009	Last day to receive a full refund of registration
15 June 2009	Last day to receive partial refund for cancellation
10 August 2009	Approximate start date for pre-conference field trips

Convenors

Patrick Williams - patrick.williams@jcu.edu.au
Nick Oliver - nick.oliver@jcu.edu.au
Brian Rusk - brian.rusk@jcu.edu.au

Website: http://sga2009.jcu.edu.au
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All information contained in this Circular is correct as of February 2009

CODES UTAS planetearth Centre for EXPLORATION TARGETING THE UNIVERSITY OF WESTERN AUSTRALIA JCU JAMES COOK UNIVERSITY

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