DYNAMICS AND EVOLUTION OF THE LITHOSPHERE – RESULTS AND PERSPECTIVES OF EARTH SCIENCES RESEARCH IN MEXICO

SPECIAL VOLUME – PART 2

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INTRODUCTION

This number of Geofísica Internacional includes the second part of a special volume on the "Dynamics and Evolution of the Lithosphere". The volume, which is edited as part of the activities of the National Committee for the International Lithosphere Program (ILP), constitutes the second volume published. The first, also consisting of two parts, was published in Geofísica Internacional, volume 25, number 1, p. 1 - 249 and number 4, p. 481 - 608 (1986). The first part of the present volume was published in volume 27, number 4, p. 463 - 663 (1988); the appendix gives the list of the corresponding contents. The ILP was established by the International Council of Scientific Unions (ICSU), with the objectives of constituting the major interdisciplinary research project in geosciences and to become a solid efficient link between the respective unions, the International Union of Geodesy and Geophysics (IUGG) and the International Union of Geological Sciences (IUGS). The establishment of ILP follows a long successful tradition of international programs organized by the two unions in the previous decades since the International Geophysical Year of 1957 - 1958 and includes the Upper Mantle and the Geodynamics Programs of the 1960's and 1970's decades. The international programs follow the recognition that increasing better understanding of past, present and future working of our planet can best come from interdisciplinary studies.

The main theme of the Lithosphere Program is the study of the origin, evolution, dynamics, and past and present characteristics of the lithosphere, with particular emphasis on the continents and margins. The studies seek to provide an understanding of Earth resources and natural hazards, aspects on which human society and life on Earth depend for their well-being. As current yet temporary members of the life community of planet Earth, it is our responsibility to endeavour for a global percep-

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tion of the Earth as a system, including the lithosphere, Earth's interior and biosphere. It is becoming increasingly clear that any effort in understanding Earth evolution must consider the variety of processes present across spatial and temporal scales. Core and mantle processes are major factors in 'surficial' plate tectonic processes, deeply influencing life through changing geography, volcanism and tectonics. Life itself has significant effect on lithospheric and deep interior processes, through changing balance of the atmosphere and hydrosphere, chemistry of sedimentary deposits, weathering, and variable nature of ocean waters and marine sedimentary deposits. The fact that a single species possess the capability of significantly altering the Earth's balance and to produce changes on a global scale certainly merits a close and widespread attention.

The National ILP Committee, which receives no direct financial support, is mainly concerned with developing better efficient ways of: (a) involvement of interested groups and individuals in ILP activities, (b) secure adequate funding, particularly for interdisciplinary projects, (c) establishment of cooperation at different levels, from institutions to individuals, including interrelationships with ILP working groups and coordinating committees, (d) discussion and assessment of short- and long-term programs and objectives, and (e) encouragement and development of rational interdisciplinary research projects among the Earth sciences community of Mexico. The Committee then endeavours to optimize the very limited economic and human resources available. Activities are currently summarized in the ILP Newsletters (1986, 1987, 1988 and 1989) and in reports published in Geos or distributed informally. The Committee has also initiated the publication of its journal LITOSFERA, which is published twice a year and is open to all interested researchers (instructions for authors may be obtained from the Committee and editor).

As already mentioned in the first part, the present volume has attempted to include papers with geophysical and geological emphasis, clearly encouraging interdisciplinary studies, which we hope can be stimulated. Earth sciences are in the midst of a major scientific quest, developing a global paradigm which is influencing every field from Geology, Geophysics, Biology, Atmospheric sciences, Planetary sciences, etc. and force ever increasing joint approaches. This second part includes eleven contributions from a wide variety of institutions, backgrounds and interests, which we expect will be useful to the Earth science community.

In the first paper, A. Albrecht and D. G. Brookins (University of New Mexico,

USA) report major and trace element, geochemical and strontium isotopic data for the thick and extensive Tertiary igneous province of the Sierra Madre Occidental, Chihuahua State, northern Mexico. This region of Chihuahua is interesting from a variety of view points besides the study of the extensive igneous province itself, which is one of the world largest continuous rhyolitic provinces (Cameron *et al.*, 1986; Urrutia-Fucugauchi, 1986). The volcanics cover the southern edge of the North American craton (Stewart, 1988), the boundary between accreted terranes (Campa-Uranga and Coney, 1983), the Mojave - Sonora Megashear (Anderson and Schmidt, 1983), and the Oaxaca - California Megashear (Hagstrum *et al.*, 1987). Albrecht and Brookins then investigate whether geochemistry of the igneous rocks can be used as a tracer of variations in basement composition. The study is concentrated in two areas with apparently contrasting basements, *i.e.* San Buanaventura, northwestern Chihuahua (Precambrian cratonic basement) and El Divisadero del Cañón del Cobre, southwestern Chihuahua (accreted terranes basement). Comparison of the geochemical data for the two areas shows marked contrasts in Sr-isotopes, K, Ti, Th-group and REE (rare earths) compositions, then supporting the initial contention of Albrechts and Brookins that the igneous suites can be used as indicators of variations in basement composition.

In the next paper, J. M. Stock (Harvard University, USA) presents a detailed geologic and K-Ar dating study of the Cenozoic rocks of northeastern Baja California Norte. Her study concentrates on the pre-Pliocene volcanic activity, from 20 to 6 Ma. This time interval includes a major geodynamic process, *i.e.* the transfer of Baja California Peninsula from North America plate to the Pacific plate, which according to Stock and Hodges (1989) began some 12 - 10 Ma ago. The opening of the Gulf of California is certainly one of the most interesting and complex events which characterize the Cenozoic history of western North America. The drift of Baja California Peninsula and Gulf opening is in a global scale related to major plate interactions (Atwater, 1970). In a closer view, the process seems far more complex and several evolutionary models have been advanced and discussed in the past years. Gulf opening has been linked to large-scale extension, often separated into two sequential events, *i.e.* the middle to late Miocene proto-gulf extension and the 5.5 Ma to the present opening (*e.g.* Moore and Buffington, 1968; Gastil *et al.*, 1979; Stock and Hodges, 1989). Volcanic activity and extensional faulting around the Gulf are important in establishing the details of the Gulf and Baja California Peninsula history.

The third paper, by G. R. Keller and R. Dyer (University of Texas at El Paso,

USA), presents an analysis of gravity data from west Texas and northern Mexico and a brief discussion on the structure and tectonics of the Paleozoic margin of North America. The Marathon - Ouachita orogenic belt constitutes a most prominent structural and tectonic feature in southeastern United States and is currently interpreted in terms of late Paleozoic plate convergence. The trend of the orogenic belt is interrupted at the Río Bravo region with no apparent geometric or geologic constraints. The lack of Paleozoic exposures restricts paleogeographic interpretations which should rest on deep drilling and geophysical data. In northern Mexico, the tectonic and paleogeographic relations are further complicated by large scale faulting such as the Mojave - Sonora megashear and other major systems (Anderson and Schmidt, 1983; Urrutia-Fucugauchi, 1984). Sánchez-Alvarez (1989) has also presented an interpretation of regional geophysical and deep drilling data for the area and delineated the major paleogeographic elements and the tectonic relationships. In this paper, Keller and Dyer interpret two prominent features, the Central Basin Platform and the Tascotal Uplift, characterized by linear gravity highs, in terms of late Paleozoic reactivation of mafic cores of failed or incipient rifts formed in the late Precambrian - early Paleozoic development of the North American cratonic margin.

In the fourth paper, J. Urrutia-Fucugauchi (UNAM, Mexico) presents an evolutionary model for pull-apart basins in terms of rotation of the basin domain as the dominant mechanism. Pull-apart basins form by strike-slip motion at discontinuities or sharp bends of lateral faults. Pull-apart structures are a common feature at transform plate boundaries and intraplate tectonic settings (*e.g.* San Andreas - Gulf of California right-lateral transform system, Polochic - Motagua left-lateral transform system, or volcanic province of central Mexico). The structures exhibit a scale independence, despite the wide range of dimensions and tectonic settings, with a rhombus-like shape and a half-length to width ratio of about 1.6. The evolutionary model proposed and the relationships examined are then briefly discussed in terms of similar relations involved in widely different, traditionally separated fields. For instance, in Archaeology and Arts with the 'golden section' used in paints and constructions, in Biology and Paleontology with the spiral growth of plants and organisms, in Mathematics with the geometric progression of Fibonacci, and recently in certain chaotic dynamic systems where randomness presents an underlying geometric form and simple deterministic systems containing few elements still generate random behaviour and suggest casual relationships (Urrutia-Fucugauchi, 1989).

In the next paper, L. A. Delgado-Argote (presently at CICESE, Mexico) reports on a study of the Jurassic - Cretaceous volcanic - sedimentary sequence of the Cuicatlán - Tehuacán area, Puebla, southern Mexico. Discussion of regional tectonic implications is in terms of the tectonostratigraphic terrane concepts and concentrates on the Juárez terrane of Campa-Uranga and Coney (1983) (referred to as Cuicateco in this contribution) and the relationships with neighboring terranes, namely Oaxaca and Maya (Campa-Uranga and Coney, 1983). The tectonics and paleogeography of the Juárez terrane certainly represent critical components in the evolution of southern Mexico and Gulf of Mexico - Caribbean region (Carfantan, 1983; Morán-Zenteno, 1987).

In the next paper, G. Carrasco-Núñez (presently at Michigan Technological University, USA) reports on the volcanic region of Los Azufres, Michoacán - El Zamorano, Querétaro. Carrasco-Núñez concentrates on the tectonic setting and the stress field, showing the presence of three fracture systems which affect the volcanic structures. The E-W direction for the maximum horizontal stress is interpreted in terms of a distensive regime during the Quaternary. The structure, tectonics and stress field for the Trans-Mexican volcanic belt have lately been receiving increasing attention in studies that emphasize the genetic relationships between volcanic activity and tectonics (*e.g.* Johnson and Harrison, in press).

In the next paper, J. O. Campos-Enríquez (presently at University of Karlsruhe, FRG), J. Urrutia-Fucugauchi (UNAM, Mexico) and M. A. Arroyo-Esquivel (presently at University of Frankfurt, FRG) present preliminary estimations of the Curie point isotherm for the western sector of the Trans-Mexican volcanic belt (TMVB) and briefly discuss the implications for the geothermal potential of the area. Depth estimations are derived from spectral analysis of aeromagnetic data along seven profiles. The corresponding Curie point isotherm lies between 7 and 18 km deep. Temperature distribution, despite its importance in understanding the dynamics of tectonic and volcanic processes, is one of the most poorly determined geophysical parameters. This is mainly due to difficulties in accurately determining temperature at depths beyond those of mines and wells. Uncertainties in heat transport modes and thermal properties or in mineral equilibria and alterations restrict the use of geotherms from thermal models and xenolith studies, respectively. The alternative approach taken by Campos-Enríquez and coworkers, *i.e.* the Curie temperature from magnetic data, is also constrained by a number of factors, *e.g.* assumptions in the magnetic source geometry and statistical nature of magnetization and geometry, the

zero-level of aeromagnetic anomalies, remanent magnetization contribution, and regional-residual separation. Additionally, the magnetic bottom estimated from the spectral analysis should correspond to the Curie point isotherm, which was adequately interpreted for the magnetic mineral of the source bodies. Examples of application of the aeromagnetic method can be found in Bhattacharyya and Leu (1975), Byerly and Stolt (1977) and Shuey *et al.* (1977). In general, as seems to be the case for the TMVB, results compare favorably with results derived from heat flow data and regional geologic studies.

In the next paper, M. Carrillo-Martínez (UNAM, Mexico) presents a structural analysis of two superimposed Jurassic lithostratigraphic assemblages of the Sierra Madre Oriental Fold and Thrust Belt of east-central Mexico. As stated by the author in the introduction, evolution of eastern Mexico during Jurassic - Neocomian time was associated with development of the Gulf of Mexico, corresponding to extentional regime in a passive continental margin. A compressional or strike-slip regime followed during Paleocene-Eocene time. The Sierra Madre Oriental Fold and Thrust Belt (Suter, 1987) presents some 40% bulk shortening. Description of the lithostratigraphic assemblages corresponds to areas west and east of the Higuerillas Thrust. To the west, the westerly magmatic-arc association assemblage of Middle-Late Jurassic (?) age and the easterly assemblage consisting of breccias, conglomerates, acid volcaniclastic rocks of Late Kimmeridgian to Early Tithonian age. To the east, the sequence is reported as covering a larger area, there the siliciclastic unit was deposited at a time the shelf was affected by high angle normal faulting. El Frontón Fault Zone is considered as the limit between the two assemblages, being characterized by a series of imbricate thrust slices.

The next paper by Ch. B. Connor (presently at Florida International University, USA) reports on anomalous soil mercury concentrations in the Paricutín volcano, providing information on the convective gas-fluid system. The high soil Hg concentration is documented for a one square-kilometer area in the southwest flank of the cone. Relatively high soil Hg concentrations are also observed for the Michoacán - Guanajuato volcanic field, with higher values near cinder cone alignments. The high mercury levels are atributed to a high fault density in this volcanic field.

The next contribution by R. Padilla y Sánchez and coworkers (DICT, Facultad de Ingeniería, UNAM) is in the form of a map (included in the annex), the Tectonic Map of Mexico. Among the many interesting features of the new Tectonic Map, it

offers the advantage of versatility since it has been generated from a PC-data file. Due to printing limitations the Map is published into two separate sheets and in a scale not enough to resolve the details included in a larger version permitted by the data file. We apologize the readers and potential users for these inconveniences.

The next paper by G. R. Keller, J. M. Hoffer, J. H. Hinojosa, J. R. Dyer (University of Texas at El Paso, USA) and L. V. Aiken (University of Texas at Dallas, USA) reports on the extension of the Río Grande rift into Chihuahua, northern Mexico. This short paper deals with an interesting and intriguing tectonic problem, which although long recognized, has received relatively little attention. The authors discuss the enigmatic southern rift extension by using gravity and seismic data. In recent years the Río Grande rift has got widespread attention, being the site of interdisciplinary studies (*e.g.* Riecker, 1979; Keller, 1986). The 'Chihuahua' extension has been studied in other works. For instance, Gries (1979) discussed structural styles and evaporite tectonics. Smith and Jones (1979) reported on thermal anomalies and crustal thinning from heat flow data and delineated a farther southward continuation of the Río Grande rift into Mexico.

Work as guest editor for the two parts of this volume has been greatly facilitated by the assistance in the evaluation procedure by R. J. Arculus (University of Michigan, USA), M. A. Armienta (Instituto de Geofísica, UNAM), H. Böhnel (Instituto de Geofísica, UNAM), C. Caballero (Instituto de Geofísica, UNAM), K. Cameron (University of California at Santa Cruz, USA), J.-Ch. Carfantan (University of Savoie, France), G. Carrasco-Núñez (Michigan Technological University, USA), S. Chávez (Fundación J. Barros Sierra, México), L. Delgado-Argote (CICESE, Ensenada, Baja California, México), J. Durazo (Instituto de Geofísica, UNAM), R. G. Gastil (San Diego State University, USA), E. González-Partida (IIE, Cuernavaca, México), W. Hildreth (US Geological Survey, USA), B. D. MacDonald (State University of New York, USA), G. Mahood (University of California at Santa Cruz, USA), L. Manzanilla (Instituto de Investigaciones Antropológicas, UNAM), F. Medina Martínez (Instituto de Geofísica, UNAM, Baja California, México), D. J. Morán-Zenteno (Instituto de Geofísica, UNAM), L. Munguía (CICESE, México), J. F. W. Negendank (University of Trier, FRG), J. Nieto-Obregón (DICT, Facultad de Ingeniería, UNAM), F. Núñez-Cornú (Instituto de Geofísica, UNAM), F. Ortega-Gutiérrez (Instituto de Geología, UNAM), R. Padilla y Sánchez (DICT, Facultad de Ingeniería, UNAM), G. Pasquaré (University of Milano, Italia), R. M. Prol-Ledezma (Instituto de Geofísica, UNAM, M. Ruiz C. (DEP, Facultad de Ingeniería, UNAM), G. Sánchez Rubio (Instituto de Geología, UNAM), O. Sánchez Zamora (Instituto Oceanográfico de Manzanillo, México), G. Silva R.

(DICT, Facultad de Ingeniería, UNAM), M. Suter (Instituto de Geología, UNAM) and I. Yokoyama (Instituto de Geofísica, UNAM). It is a pleasure to acknowledge their efficient collaboration. The responsibility clearly remains on the editor. Thanks are also due to the Editorial Staff of the Journal and to the Graphics and Reproduction Department of the Instituto de Geofísica, UNAM.

This is Inter-Union Commission on the Lithosphere ICL-Publication number 0173 and ICL National Committee - Mexico Publication # SV - 04.

APPENDIX

DYNAMICS AND EVOLUTION OF THE LITHOSPHERE – RESULTS AND PERSPECTIVES OF EARTH SCIENCES RESEARCH IN MEXICO

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