TSSZ-1

SEISMIC AND THERMAL STRUCTURE OF MEXICO AND MIDDLE AMERICA FROM INVERSION OF SEISMIC SURFACE WAVES

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We have obtained a three-dimensional shear-velocity model of the crust and upper mantle beneath Mexico and Middle America by simultaneous inversion of broadband group and phase velocity dispersion curves of fundamental-mode Rayleigh and Love waves.

The model is parameterized in terms of velocity depth profiles on a discrete 2 x 2 degree grid. The model is isotropic for the crust and for the upper mantle below ~220 km but, to fit simultaneously long period Love and Rayleigh waves, the model is transversely isotropic in the shallow part of the uppermost mantle.

The inversion for shear velocity model breaks into two principal steps. The first step is the surface wave tomography in which dispersion maps are produced for a discrete set of periods for each wave type (Rayleigh group velocity, 18 - 200 s; Love group velocity, 20 - 150 s; Rayleigh and Love phase velocity, 40 - 150 s). We use \»diffraction tomography\» based on a physically motivated scheme of the damping and, as a consequence, providing a more realistic estimation of the resolution of the tomographic maps.

The second step is a Monte-Carlo inversion yielding an ensemble of acceptable models at each spatial node. We refer to the features that appear in every member of the ensemble as “persistent”.

The resulting shear-velocity structure is converted into temperature structure based on laboratory-measured properties of individual minerals, Voigt-Reuss-Hill averaging scheme, and an average mineralogical composition of the mantle. Our results show that temperatures in the back-arcs vary strongly along the Middle American Trench with a relatively cold and thick lithosphere apparent beneath the Yucatan and Chortis Blocks and the lithosphere nearly absent beneath the Mexican Volcanic Belt. The variations in thermal and elastic properties of the back-arc lithosphere can be one of the factors contributing to the along-strike variability of the subduction characteristics of the Cocos Plate.

TSSZ-2

“COLD” WAVES, “COLD” PLUMES AND INCIPIENT MAGMA CHAMBERS ABOVE SLABS

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It is commonly thought hot diapiric and porous fluid/melt flows prevail in the mantle wedge above the subducting slab. However, hydration and partial melting along the slab can create a situation in which a Rayleigh-Taylor instability can develop at the top of a cold subducting slab. Using a realistic upper mantle model with an unprecedented spatial resolution of around 100 m, we have investigated the multi-resolutional character of thermal-chemical upwellings and incipient magma chambers forming under oceanic arcs. We have used up to 50 million markers on a shared-memory computer for delineating the complex multiscale structures in the viscosity, accumulated strain, and composition of this multicomponent system with 12 different constituents. The output of these simulations offers a great challenge for understanding the underlying chemical, physical and geological phenomena. We have developed a web-based visualization tool, WEB-IS (http://tomo.msi.umn.edu/~max/) for interrogating the data and zooming into the details. Modeling, aided by visualization, shows that rising diapiric structures, colder than the asthenosphere by 300 to 400 degrees, are driven upward by compositional buoyancy. These “cold plumes” with a compositional, hydrous origin, launched from a depth of greater than 100 km, are lubricated a lot by viscous heating, have an upward velocity in excess of 1 m/yr and rapidly transport material to form primary magma chambers under volcanic arcs. Inverted temperature structures and transient bimodal magmatism are plausible consequences of conductive and shear heating of relatively cold hydrated material of the incipient magma chambers in the hot mantle wedge. We have also discovered wave-like structures (“cold” waves) propagating upward along descending slabs and consisting of compositionally buoyant hydrated partially molten subducted crustal and mantle material. Apart from periodic feeding of the magma chambers, “cold” waves may also transport upward thousands of cubic kilometers of subducted material and may cause the rapid exhumation of ultra high-pressure rocks along slabs. There may be a spatial correlation between seismicity and the particular depth of cold plume and cold wave initiation.

TSSZ-3

GEOLOGIC CONSTRAINTS ON CENOZOIC MANTLE EVOLUTION BENEATH THE CENTRAL PART OF THE MEXICAN SUBDUCTION ZONE (LONG. 101°W - 98°W)

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Different set of geophysical data consistently indicate that the region immediately to the south of the central TMVB (Long. 101°W – 98°W) is underlain by the Cocos plate flat slab almost in direct contact with the North America crust. The same data also indicate that beneath the TMVB the upper mantle has a relatively low density and high temperatures. The Cenozoic tectonic and magmatic evolution of this region shows that this unusual situation is the result of a progressive mechanical and thermal removal of mantle lithosphere. The first episode in this process is related to the change of the North America margin from transform (Caribbean- North America) to northward-directed subduction (Cocos-North America). This event, which started in late Oligocene times at the Longitude of Acapulco, produced a mechanical removal of the mantle lithosphere and part of the crust by subduction erosion. The process was completed by early Miocene, when a new volcanic arc began to form in a more inland location (Cuernavaca-Malinalco, Ferrari et al., this volume). From 20 to 10 Ma this intermediate volcanism migrated farther away from the trench, toward the NE. The youngest (12-10 Ma) and most inland centers (Palma Sola, Cerro Grande, Apan area, Zamorano, Palo Huerfano) form a WNW-ESE belt with an adakitic signature (Gomez-Tuena et al., 2003; Ferrari unpublished data). The progressively inland position of the arc and the slab melt signature of the recentmost products suggest that the subducted slab changed from moderately dipping to flat beneath the TMVB. As a consequence part of the mantle lithosphere beneath the central TMVB must have been removed at this time. From ~9 and 3.5 Ma volcanism is absent in the region between Mexico City and Pachuca but mafic volcanic pulse related to an episode of slab detachment is observed to the north at ~8 – 6.5 Ma (Ferrari, 2003, submitted to Geology). Regional ignimbrites and dacitic to rhyolitic domes are emplaced shortly after in a belt located to the south (Amazcala, Apaseo, Los Azufres, Amealco, Huichapan, Catedral, and north of Pachuca). I speculate that the removal of the flat slab after detachment may have exposed an already thinned mantle lithosphere to higher temperatures provoking its partial melting and silicic volcanism at surface. Since Late Pliocene volcanism moved again to the south and almost reached the Latitude of Cuernavaca by the Holocene. The volcanic front shows an extreme geochemical variability, including lavas with no evidence of subducting fluids (OIB in Sierra Chichinautzin), lavas with strong slab melting signature (adakites of Nevado de Toluca and Zitacuaro) and lavas whose source show clear evidence of fluids from the subduting plate (Valle de Bravo, Sierra Chichinautzin). The trenchward migration of volcanism and the geochemistry of Quaternary lavas suggest that the leading edge of the slab rolled back while it is dehydrating and melting. At the same time enriched sub-slab asthenosphere is flowing around the edge of the slab. This implies that the present mantle wedge is relatively small, highly heterogeneous, and characterized by a low viscosity.

TSSZ-4

PETROLOGICAL, GEOCHEMICAL, AND ISOTOPIC STUDIES OF RECENT TO PLEISTOCENE POPOCATÉPETL VOLCANO: MAGMA GENERATION SCENARIOS

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A study of Late Pleistocene to Recent products of Popocatépetl (Popo) volcano and surrounding scoria cones was undertaken to better establish their genetic relationship and magmatic history. Popo and flanking vents are located within the central portion of the Trans Mexican Volcanic Belt, which is related to oblique subduction of young oceanic lithosphere. Current activity of Popo can be understood in the context of its past eruptions and those from surrounding scoria cones. The latest cycle of eruption began Dec. 21, 1994 with continuous to pulsating emission of phreatic ash. The last important event happened on July 19, 2003, covering Mexico-City with a thin ash-layer.

Both Popo and surrounding scoria cones produced moderate-K, calc-alkaline rocks, with the two groups differing mainly in degree of differentiation, water content, and oxidation state. Some vent samples on the immediate flanks of Popo and have phenocryst assemblages and compositions transitional between typical flanking vent and stratovolcano samples. Monogenetic vents produced mainly basaltic andesites to andesites, primarily by crystal fractionation of Ol (Fo80-90)+chromite, 2Pyx±Ol, and 2Pyx±Plag±Hb assemblages, with minor assimilation of crustal debris. The andesitic to dacitic rocks of Popo are dominated by Plag-2Pyx-2Oxide±Hbl assemblages, with variable amounts of Ol (Fo70-90)+chromite xenocrysts. A few Popo samples contain locally abundant xenolithic debris of cognate-granitoid intrusions and their metasedimentary wallrocks. The two suites share parental Mg-rich basaltic andesite magmas, with the Popo magmas reflecting longer residence in the crust, and enhanced hydration and oxidation due to the resulting processes of crystallization, recycling, assimilation, and degassing in relatively evolved magma chambers. The 1996 and 1997 dome eruptions confirm that dacitic magma currently resides beneath Popo and is episodically recharged by more mafic magma, fostering eruption and excess degassing. Two-oxide thermometry and the presence of FeCu sulfide globules confirm that these magmas erupted at T = 930ºC and fO2 = -10.2 log, below anhydrite stability.

87Sr/86Sr, ?-Nd and 206Pb/204Pb ratios are between 0.70365 and 0.70463, +6.4 and +3.0, and 18.618 and 18.781, respectively. Andesitic to dacitic rocks of Popo formed by mafic recharge, fractionation, and mixing of dacitic to basaltic magmas in mature crustal chambers. Plagioclase accumulation and recycling related to protracted fractionation and assimilation of earlier emplaced magmas and their wallrocks was also important.

TSSZ-5

THERMAL, MANTLE WEDGE FLOW AND BLOB TRACING MODELS FOR THE MEXICAN SUBDUCTION ZONE

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The origin of the Central Mexican Volcanic Belt (CMVB) and a bearing of the subducting Cocos plate on the CMVB volcanism are still controversial. In this study, the temperature and mantle wedge flow models for the Mexican subduction zone are developed using finite element technique to investigate the thermal structure below CMVB. The numerical scheme solves a system of 2D Navier-Stokes equations and a 2D steady state heat transfer equation.

Two models are considered for the mantle wedge: the first one with a constant viscosity (isoviscosity) and the second one with strong temperature dependent viscosity. The first model reveals the maximum temperature of ~800 ºC in the mantle wedge and at the base of the continental crust, which is not sufficient for the melting, as well the geotherm of the subducting plate upper surface does not pass the solidus for mafic minerals. The second model predicts the temperature of more than 1200 ºC beneath the CMVB. This should result in the melting of the subducting plate starting at the depth of ~ 62 km. As the temperature is of 800 ºC at 30 km depth and exceeds 1000 ºC at the base of the continental plate, there is another possible source of the volcanism within the lower continental crust.

Considering that the main component of the volcanic material is generated by the melting processes on the subducting plate surface, a dynamic model simulating the motion of detached blobs in a viscous mantle wedge flow was developed. The blob's motion is determined by the action of drag, mass, and buoyancy forces in the mantle wedge velocity field. The blobs of the realistic diameter of 0.2 - 2.0 km show very different trajectories only at very low wrapping viscosity (h ~ 1015 Pa×s). The blob rise time which is necessary to reach the bottom of the continental crust is from 0.04 up to 12.5 million years depending on the plume diameter and surrounding viscosity.