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Geology, geochronology and tectonic setting of late Cenozoic volcanism along the southwestern Gulf of Mexico: The Eastern Alkaline Province revisited

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Abstract

A NNW-trending belt of alkaline mafic volcanic fields parallels the Gulf of Mexico from the U.S. border southward to Veracruz state, in eastern Mexico. Previous studies grouped this volcanism into the so-called "Eastern Alkaline Province" (EAP) and suggested that it resulted from Gulf-parallel extensional faulting migrating from north to south from Oligocene to Present. On the basis of new geologic studies, forty-nine unspiked K–Ar and two ^{40}Ar–^{39}Ar ages, we propose a new geodynamic model for the volcanism along the southwestern Gulf of Mexico.

We studied in detail four of the six recognized fields of mafic alkaline volcanism in Veracruz state: 1) The lavas flows of Tlanchinol area (7.3–5.7 Ma), 2) the Alamo monogenetic field and Sierra de Tantima (7.6–6.6 Ma), 3) the Poza Rica and Metlatoyuca lava flows (1.6–1.3 Ma) and 4) the Chiconquiaco–Palma Sola area (6.9–3.2 Ma). Other two mafic volcanic fields may represent the continuation of alkaline volcanism to the southeast: the Middle Miocene lavas at Anegada High, offshore port of Veracruz, and the Middle to Late Miocene volcanism at the Los Tuxtlas.

The existence of major Neogene extensional faults parallel to the Gulf of Mexico (i.e., ~N–S to NNW–SSE) proposed in previous works was not confirmed by our geological studies. Elongation of volcanic necks, vent alignment, and faults mapped by subsurface data trend dominantly NE to ENE and NW to NNW. These directions are parallel to transform and normal faults that formed during the Late Jurassic opening of the Gulf of Mexico. Ascent of mafic magmas was likely facilitated and controlled by the existence of these pre-existing basement structures.

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Coupled with previous studies, our data demonstrate the occurrence of three magmatic episodes in Veracruz: 1) A Middle Miocene (~15–11 Ma) episode in southern Veracruz (Palma Sola, Anegada, and Los Tuxtlas); 2) A Late Miocene to Early Pliocene (~7.5–3 Ma) pulse of mafic alkaline volcanism throughout the study region; and 3) A Late Pliocene to Quaternary transitional to calc–alkaline volcanism in southern Veracruz (Palma Sola, Los Tuxtlas). Whereas the first and third episodes may be considered part of the subduction-related Trans-Mexican Volcanic Belt, the second pulse of mafic alkaline volcanism has a more complex origin. The absence of significant extensional faulting precludes a rift origin. We favor a model in which a transient thermal anomaly and melting of the mantle was triggered by the tearing and detachment of part of the subducted slab.

Keywords: alkaline volcanism; tectonics; eastern Mexico; Gulf of Mexico; geochronology; late Cenozoic

1. Introduction

In the early days of the plate tectonics theory, the occurrence of alkaline volcanism was generally related to intra-plate tectonic settings distinct from convergent plate boundaries. In recent decades, however, alkaline volcanism has been recognized in virtually every tectonic environment, including many continental volcanic arcs worldwide (see Lange and Carmichael, 1991, for a review). Alkaline volcanism at convergent plate boundaries has been inferred to be associated with slab-induced asthenospheric corner flow (Toksöz and Bird, 1977), slab-window formation (Dickinson and Snyder, 1979; Hole et al., 1995), slab roll-back (Furlong et al., 1982), and combination of slab windows and mantle plumes (e.g., Abratis and Worner, 2001).

Cenozoic alkaline volcanism is widespread in eastern Mexico but its relation with the southern Mexico subduction zone (Fig. 1) is unclear. A roughly north–south belt of Tertiary mafic alkaline volcanic fields runs from the U.S. border to the southern Veracruz State (Fig. 1), intersecting the subduction-related Trans-Mexican Volcanic Belt (TMVB) (Ferrari et al., 1999) in central Veracruz. Spanning over 1500 km in length, this zone of mafic volcanism constitutes a prominent feature in the geology and geomorphology of eastern Mexico, which otherwise is dominated by Mesozoic to early Tertiary marine and late Tertiary nonmarine sedimentary successions. Robin (1976, 1982) defined the belt of mafic alkaline volcanism as the "Eastern Alkaline Province" (EAP hereafter) and, based on a number of conventional K–Ar datings and mostly major elements geochemistry, suggested that it represented intraplate-type volcanism migrating from north to south from Oligocene to Present. In the Robin (1982) model, the EAP would be the result of Gulf-parallel extensional faulting and would be unrelated to the subduction of the Cocos plate; however he reported that during the Pliocene the products of alkaline volcanism alternated with arc-related lavas of the eastern TMVB in the Veracruz region. Subsequent geochemical and isotope studies questioned this model, at least for the southernmost part of the EAP. Besch et al. (1988) and López-Infanzon (1991) show that the Chiconquiaco–Palma Sola volcanic field has a geochemical imprint of fluids from the subducting plate. Gómez-Tuena et al. (2003) provided a more detailed petrologic study of the three volcanic successions of this area. They interpret the chemical and isotopic characteristics of the Neogene volcanism at Palma Sola as controlled by variation in time of the depth of the subducting Cocos slab. Similarly Nelson et al. (1995) recognized a variable subduction signal for the Los Tuxtlas volcanic field, for which they suggest an analogy with lavas erupted in back-arc settings in Japan and the Andes. Such data would indicate that at least part of the EAP could represent the continuation of the arc volcanism of the TMVB toward the southeast (Fig. 1). If so, the mere existence of a single volcanic province would be under question. However, with the notable exception of the Los Tuxtlas volcanic field (Nelson and González-Caver, 1992), after the Robin (1982) synthesis the rest of the EAP has remained largely unstudied geologically and geochronologically.

In an attempt to better define the time and space evolution of the mafic alkaline volcanism in eastern Mexico, and to understand its relation with the TMVB, we undertook a geologic, geochronologic and petrologic study of the southern half of this province. In this paper we summarize the geologic