TECTONIC AND PETROGENETIC IMPLICATIONS OF THE ALTIPLANO-PUNA MAGMA BODY, CENTRAL ANDES

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SUMMARY

Since the late Miocene an ignimbrite "flare-up" has produced a major silicic volcanic province, the Altiplano-Puna Volcanic Complex (APVC), in the central Andes of South America. The APVC covers some 50,000 km^2 between 21° and 24°S and constitutes the largest ignimbrite concentration in the Central Volcanic Zone of the Andes, and one of the largest in the world (de Silva, 1989). The APVC is located at the southward transition between the ~4-km-high plateau of the Altiplano and the ~5-km-high Puna, a change that may be associated with a rapid southward thinning of the South American lithosphere. Studies of the voluminous ignimbrites by de Silva (1989) and others suggest the flare-up is due primarily to crustal melting in response to tectonic crustal thickening associated with the building of the central Andes, with a lesser contribution from subduction-related melts. The region has been the site of large-scale silicic magmatism since 10 Ma with several major caldera-forming eruptions (de Silva, 1989; Kay et al., 1998). The youngest major ignimbrite in the APVC is a 1-m.y.-old eruption from the Purico center. Late Pleistocene to Recent volcanic activity in the form of large silicic lava flows and domes and two major geothermal fields indicate that the province remains magmatically active. The APVC represents a great opportunity to study the crustal structure of a young silicic magmatic system.

INTRODUCTION

From October 1996 to September 1997 we operated seven PASSCAL broadband seismic stations in the Bolivian portion of the APVC to record teleseismic earthquakes and local Benioff zone events in the underlying subducting Nazca plate. One station was located near Uyuni outside of the APVC, and the remaining six stations were deployed over the APVC, covering an area approximately 150 km by 75 km. We used *Ps* converted phases (receiver functions) observed in teleseismic and subcrustal local earthquakes recorded on the APVC stations to detect and characterize crustal discontinuities within the APVC crust. Crustal seismic anisotropy can be detected by shear-wave splitting of the converted *S* wave or by the observation of converted *SH* phases detected on the tangential component of receiver functions. Unlike the situation with teleseismic *S* or *SKS* splitting observations, the converted *S* phase provides good estimates of the depth extent of the anisotropy.

CONCLUSIONS

Using receiver functions we have detected and delineated the lateral extent of a regionally pervasive low-velocity layer associated with the APVC. We found that Vs must be close to zero ($Vs < 0.5$ km/s) in the low-velocity layer and have a thickness of about 1 km to match the data for the Laguna Colorado station. We interpreted the low-velocity layer as a regional sill-like magma body associated with the Altiplano-Puna Volcanic Complex, and we named it the Altiplano-Puna magma body (APMB) (Chmielowski et al., 1999). To first order, the APMB appears to correlation with the 10–3 Ma ignimbrite volcanic centers (Kay et al., 1998) and not with the Quaternary arc volcanoes. The depth to the top of the APMB is consistent with a rheological control on the emplacement of this sill-like body that separates a brittle upper crust and a more ductile lower crust. Based on its approximate areal extent and thickness, the regional low-velocity layer has a minimum volume of ~60,000 km^3. The strong nonlinearity of the relationship between seismic velocity and the percentage of melt in a rock makes it difficult to estimate the amount of melt. Using existing experimental and theoretical relationships (e.g., Makovsky and Klemperer, 1999), our extremely low Vs estimates requires more than 15% melt. Even such a minimum percentage leads to an estimate of 9000 km^3 of melt, although it could be substantially greater. We speculate that this magma body is a storage/accumulation level for silicic melt between a lower crustal/upper mantle magma generation zone and shallower caldera-forming plutons.

Large-amplitude *P-SH* conversions in both the teleseismic and local data appear to originate from the top of the APMB. Using the method of Levin and Park (1998), we computed synthetic receiver functions for several simple layered anisotropic media. Tilted-axis anisotropy in the upper crust can produce *Ps* and *Psh* conversions at the appropriate time but these phases do not have the consistent polarities observed in the data. It is interesting to note that upper crustal anisotropy involving both Vp and Vs can generate a "split *Ps*" phase that mimics the timing of the *Ps* from the top and bottom of a low-velocity layer; however, the polarities of the split *Ps* are again inconsistent with observations. Synthetics for a model with tilted-axis anisotropy within the low-velocity layer are consistent with timing and polarities for both the radial and transverse components and also fit the timing and amplitude of the bottom conversion. Although more modeling is required, we tentatively conclude that the "magma body" is characterized by tilted-axis, hexagonally symmetric anisotropy.

Possible explanations for the observed anisotropy within the crustal magma body include stress-induced alignment of melt-filled cracks or a phenocryst-rich, partially crystallized magma. In either case, we infer from the presence of significant anisotropy in the magma body that it is not completely homogenized by convective mixing in its current state of evolution. This places an upper limit on the melt fraction at about 50%. In addition, the tilted axis suggests the influence of a regional stress field on the crystallizing magma body, perhaps related to the foreland thrust belt as suggested by Sengor (1990).

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