Coeval volcanic activity and tectonic shortening, Tromen volcano, Neuquén province, Argentina

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INTRODUCTION

On planet Earth, magmatic activity concentrates at tectonic plate boundaries. Prime examples are subduction zones at convergent margins. At those of Andean type, deformation and current stresses tend to be compressional. In such a context, volcanoes and associated magmatic intrusions might be subject to horizontal compression. However, to our knowledge, young volcanic rocks in the Andes have not yet been observed to record a regional deformation, so that it is difficult to demonstrate that compression and magmatism are coeval. Because a compressional setting is in principle less favourable than an extensional one, the question is, how do magmas reach the surface (e.g. Galland et al., 2003)?

In an attempt to answer this question, we have studied the structure and development of Tromen volcano (37°S, 070°W), which is in the foothills of the Southern Andes of Argentina, on the western edge of the Neuquén basin. Tromen is a back-arc volcano, some 150 km E of the current main volcanic arc. At 3969 m, the summit dominates the eastern Neuquén basin. The entire edifice is up to 30 km in diameter (Fig. 1). Volcanic products, especially widespread lava flows, are mainly basaltic; but andesitic to dacitic volcanic domes occur at Cerro Bayo, Cerro Tilhué and close to the central summit (Fig. 1, Zollner and Amos, 1973, Holmberg, 1975). Apparently, the youngest basaltic eruptions were in the XIXth century (Simkin et al., 1981).

The substrate of the volcano consists mainly of Mesozoic sedimentary rocks, which accumulated in a rift basin (e.g. Vergani et al., 1995). Since the Late Cretaceous, the Neuquen basin has developed in a foreland setting, so that older extensional structures have been reactivated, during three main compressional phases (Peruvian, Incaic and Quechua, Cobbold and Rossello, 2003). The E-W shortening also resulted in thrusts and folds, which are manifest around Tromen volcano (Kozlowski et al., 1996).

MAJOR COMPRESSIONAL STRUCTURES

On Tromen, volcanic rocks form a thin cover, only a few hundred metres thick. Mesozoic sedimentary rocks account for most of the edifice. They crop out up to altitudes of 3000 m, close to the central summit, that is about 2000 m above the foot of the volcano. The Mesozoic strata have been tectonically uplifted in a fold-and-thrust belt, which trends broadly N-S, but bends around the foot of the volcano (Fig.1). Tromen appears to be at the centre of a doubly-vergent thrust belt, in which the main thrusts are on the eastern side and eastward-verging (Fig.2).

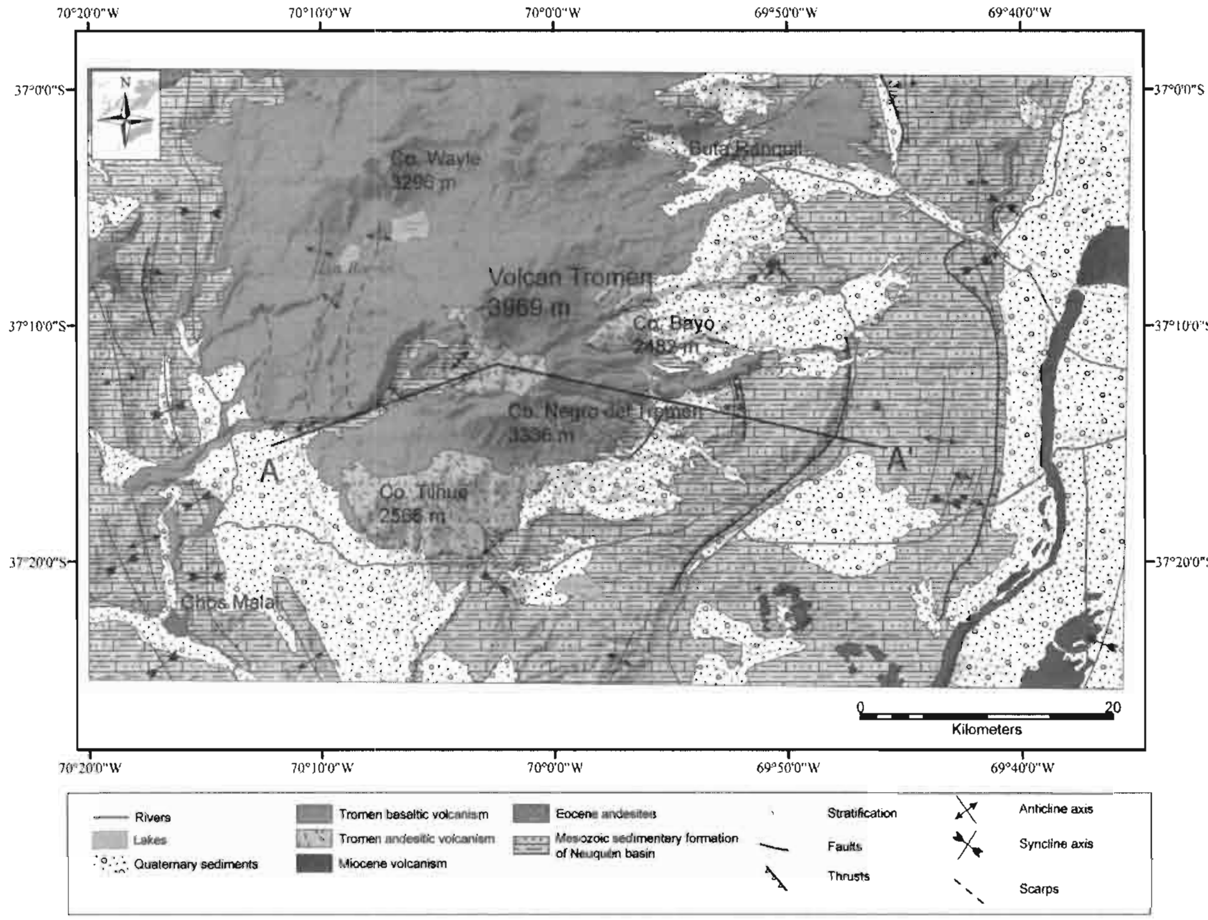

Figure 1. Structural map of Tromen volcano. For cross section A-A', see Fig. 2.

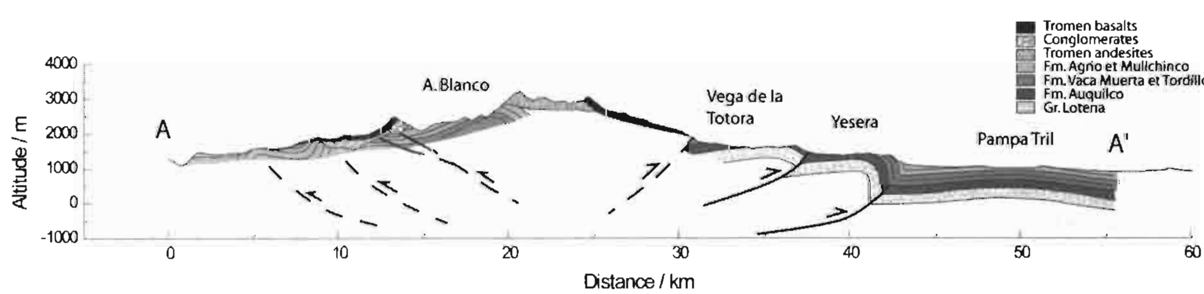

Figure 2. Regional cross section A-A'. For location, see Figure 1. Vertical scale is about twice horizontal scale.

The deep-seated shortening is of Tertiary and Quaternary age. However, the volcanic cover of the Tromen has also been shortened (Figs. 1 and 2). In the West, basaltic lava flows around Los Barros form open folds, trending broadly N-S. They continue southward, across the western lava flows of the volcano, as a series of tectonic scarps, above thrusts in the underlying Mesozoic sequence. Close to the centre of the volcano (Arroyo Blanco, Fig. 2), thrust faults crosscut feeder dykes, 1 to 2 m thick, which have intruded older andesitic to dacitic domes. Offsets on these faults are from one to several tens of metres. To the East of the volcano, tectonic breccias contain a mixture of various sedimentary rocks and conglomerate. The conglomerate contains blocks of basalt and was disrupted by tectonic events. All the tectonic structures within the Tromen lavas are similar in style and orientation to those in the sedimentary substrate and they appear to have resulted from E-W shortening.

DURATION OF VOLCANIC ACTIVITY

We have dated 26 samples from the main volcanic formations, as they were defined by Zollner and Amos (1973) and Holmberg (1975), using the laser probe ^{39}Ar-^{40}Ar dating method (Ruffet et al., 1991, Fig. 3 and 4). Volcanic rocks on Cerro Wayle and most of the youngest Tromen flows were not sampled. Most of the ages were obtained on whole rock fragments. Nevertheless, single crystals of biotite and amphibole, where present in the most differentiated samples, were also analysed. All the obtained age spectra displayed plateau ages (Fig 4). The oldest plateau age of 2.08 ± 0.13 Ma suggests that volcanic activity began during the latest Pliocene. The range of plateau ages, from 2.08 Ma to about 0.5 Ma, shows that volcanic activity was almost continuous during that period. The youngest plateau age is 0.04 ± 0.04 Ma. The historical eruptions and fresh lava flows suggest that volcanic activity has been almost continuous during the Pleistocene and Holocene.

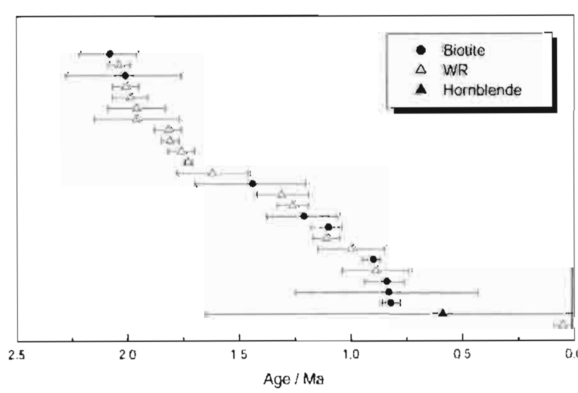

Figure 3. Spectrum of ^{39}Ar-^{40}Ar ages (1σ error bars) for volcanic rocks on Tromen volcano.

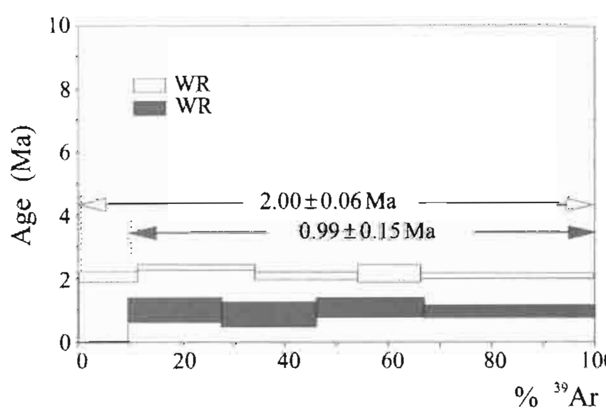

Figure 4. ^{39}Ar-^{40}Ar plateau ages (1σ error bars) for 2 samples of folded lava flows.

AGE OF DEFORMATION

Most of the shortening accumulated before the beginning of volcanic activity on Tromen, about 2 Ma ago. However, a significant amount of shortening has disturbed the volcanic rocks. The ages of faulted dykes range from about 2 Ma to about 1.61 Ma. The ages of volcanic blocks, from conglomerate within the tectonic breccias, range from about 1.95 Ma to 1.81 Ma. The folded lava flows of Los Barros give ages in the range 2.00 ± 0.06 Ma to 0.99 ± 0.15 Ma (Fig 4). These results show that compressional deformation was active less than 1 Ma ago. It is likely to be still active today.

CONCLUSIONS

1. Tromen is a large back-arc active volcano of late Pliocene to Holocene age. Its basaltic, andesitic and dacitic lavas form only a thin cover above an uplifted Mesozoic substrate.
2. The substrate underwent intense E-W shortening. The resulting folds and thrusts trend broadly N-S, but curve around the foot of the volcano.
3. Volcanic formations have also recorded a significant amount of E-W shortening compatible with that of the substrate.
4. Newly obtained ^{39}Ar-^{40}Ar ages of volcanic rocks indicate production and intrusion of magma has been almost continuous over the last 2 Ma.
5. The ^{39}Ar-^{40}Ar ages of deformed volcanic rocks indicate that most of the shortening accumulated before about 2 Ma, but that some deformation is younger than 1 Ma and may still be active.
6. We conclude that magma must have erupted or intruded while shortening was ongoing.

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