

member is in tectonic contact with the CMB. The lower layers of the Lupica Formation are more deformed than the upper ones. This indicates syntectonic deposition during extensional conditions and suggests that deformation ceased during deposition of the Lupica Formation. The presence of lacustrine deposits in this unit is an evidence for endoreic basins developed in active volcanic environments, probably caused by collapse of a caldera. These events occurred between 23 ± 0.7 Ma and 18 ± 0.7 Ma ago according to radioisotopic ages obtained in an ignimbrite layer from the floor of the middle member, and a tuff from the middle part of the upper member. We finally conclude that the Oxaya and Lupica Formations are coeval and that they were deposited during a long lasting episode of explosive volcanism and caldera development.

The Zapahuira Formation (García, 1996) forms an approximately 500 m thick series composed of andesitic, basaltic lavas and laharic flows of similar composition, that unconformably overlie the Oxaya and Lupica Formations, and the syntectonic conglomerates of the Joracane Formation. Three ages obtained in this newly defined unit fall between 11.4 ± 0.3 and 12.7 ± 0.1 Ma.

b) The syntectonic conglomerate deposits. The Joracane Formation (García, 1996) is composed by nearly 1.600 m thick conglomerates and rare volcanic intercalations. To the East, this unit is westwardly thrust by the Lupica Formation and the CMB, while to the West it thrusts also westwardly the Huaylas Formation (Fig. 1). These conglomerates are essentially composed by volcanic fragments of the Lupica Formation; calcareous clasts of the upper member of the Lupica Formation are locally present, as well as clasts of the CMB (Tignámar region). The conglomerates are of fluvial origin. They form metric to more meters thick, rather soft, layers. Measures of imbrication and the granulometric pattern indicate a sediment supply from areas located to the East. These areas were uplifted by activation of the Belén-Ticnamar. K-Ar ages on biotites from tuff levels intercalated in this conglomeratic series gave 18.2 ± 0.8 and 16.8 ± 1.5 Ma.

The Huaylas Formation (Salas et al., 1966) consists of conglomeratic deposits that unconformably overlie the Oxaya Formation and cover with progressive unconformity the units located to the East of the Copaquilla-Tignámar fault; to the west the Huaylas Formation onlap the Oxaya Formation. These conglomerates are also of fluvial origin. The sediment supply directions and the clast composition indicate a western provenance and an origin from the Lupica Formation and the CMB. The lower levels of this unit are deformed by the Copaquilla-Belén fault, while the upper levels are not deformed and extend to the East of the fault (Fig. 1). The Huaylas Formation lies over the Pampa El Muerto basalts which were dated 11.4 ± 0.3 Ma and contains Huayquerian fauna (Salinas et al., 1991). It is covered with strong angular unconformity by the 30 m thick Huaylas ignimbrite dated at 4.4 ± 0.3 and 4.8 ± 0.3 Ma (Naranjo and Paskoff, 1985).

AGE AND SEQUENCE OF THE CENOZOIC DEFORMATION

The early Miocene deposits lie directly on top of the Precambrian-early Paleozoic metamorphic complex and the marine Jurassic deposits. Cretaceous as well as early Cenozoic rocks, well exposed on the East side of the Altiplano, are not present in this region. It is, therefore, possible to conclude that the West margin of the Altiplano remained elevated and exposed to erosion for most of the Mesozoic and the early Tertiary. Early Miocene deposits accumulated in an extensive tectonic regime (most probably a caldera environment). After approximately 18 Ma the western border of the Altiplano was subjected to compressive deformation. The compressive episode, that came to an end between 8 Ma and 4-5 Ma, caused a series of westvergent folds and thrusts, and triggered the deposition of syntectonic conglomerates: Joracane and Huaylas Formations (Fig. 1).

The Joracane Formation is associated to activity of the Belén-Tignámar fault. This fault cuts across the conglomeratic series and no progressive unconformity was observed, suggesting a late reactivation phase. The activity of the Belén-Tignámar fault started at 18 Ma and stopped around 12 Ma.

The Huaylas Formation is associated to the Copaquilla-Tignámar fault. The activity of this fault began after 11 Ma and ended before 4-5 Ma, but well after 8 Ma. The synsedimentary deformation in this unit is well developed; its lower levels are folded and thrust, while the subhorizontal upper levels cover with erosional unconformity the upthrust block. The conglomeratic filling has been strongly eroded and an erosional level 100 to 150 m below the top of these conglomeratic series is sealed by the Huaylas ignimbrite. The remnants of the ignimbrite East of the Copaquilla-Tignámar fault (NW of Cerro Copaquilla) lie nearly one hundred meters above the general level of the ignimbrite, suggesting a late reactivation of the fault after 4-5 Ma.

