VALLEY EVOLUTION, UPLIFT, VOLCANISM, AND RELATED HAZARDS IN THE CENTRAL ANDES OF SOUTHERN PERU

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INTRODUCTION

Interpretation of satellite images, field work, and geochronology identify three principal types of volcanoes in the areas of Rio Cotahuasi-Rio Ocoña, and Arequipa in southern Peru (Figs. 1-3): (1) relatively youthful stratovolcanoes of Pleistocene to Recent age e.g. El Misti (≤0.8 Ma) and older, larger complexes such as Nevado Coropuna, (2) deeply eroded stratovolcanoes of Plio-Quaternary age (4-1.5 Ma) such as Nevado Solimana and Chachani, and; (3) subdued 'shield' volcanoes of Late Miocene age. While the former are rather varied in petrography and hence chemical composiotion of erupted magmas, the latter tend to be comprised more of monotonous mafic andesites. Ignimbrites form of several hundreds of km^2 in area and several tens of km^3 in volume are also observed and have been dated at middle Miocene (13-14 Ma), Pliocene (5-2 Ma), and Pleistocene age (~1 Ma) (Thouret et al., 2001).

In the area of Arequipa, 13-14 M ignimbrites outcrop above the Jurassic basement in the Rio Chili valley that cuts the flank of the Western Cordillera (Fig. 2). The upper flanks of Rio Chili valley are built in part by lava flows and volcaniclastic sediments of Plio-Quaternary age, whose sources are the Chachani massif and El Misti. Downcutting by 250 m has been achieved within the past 3 My (Fig. 2).

In contrast, the headvalleys of the deepest canyons on Earth of Rios Ocoña, Cotahuasi and Colca NW of Arequipa, have been cut 2 km down in Miocene volcanic rocks and 1 km further down in Cretaceous intrusive and Jurassic sedimentary rocks. The headvalleys were repeatedly filled by pyroclastics and lava flows of Neogene age (< 1 Ma, Fig. 3) and have subsequenty been recut below their original thalweg. These canyons are thus much deeper and older (middle Miocene) than Rio Chili.

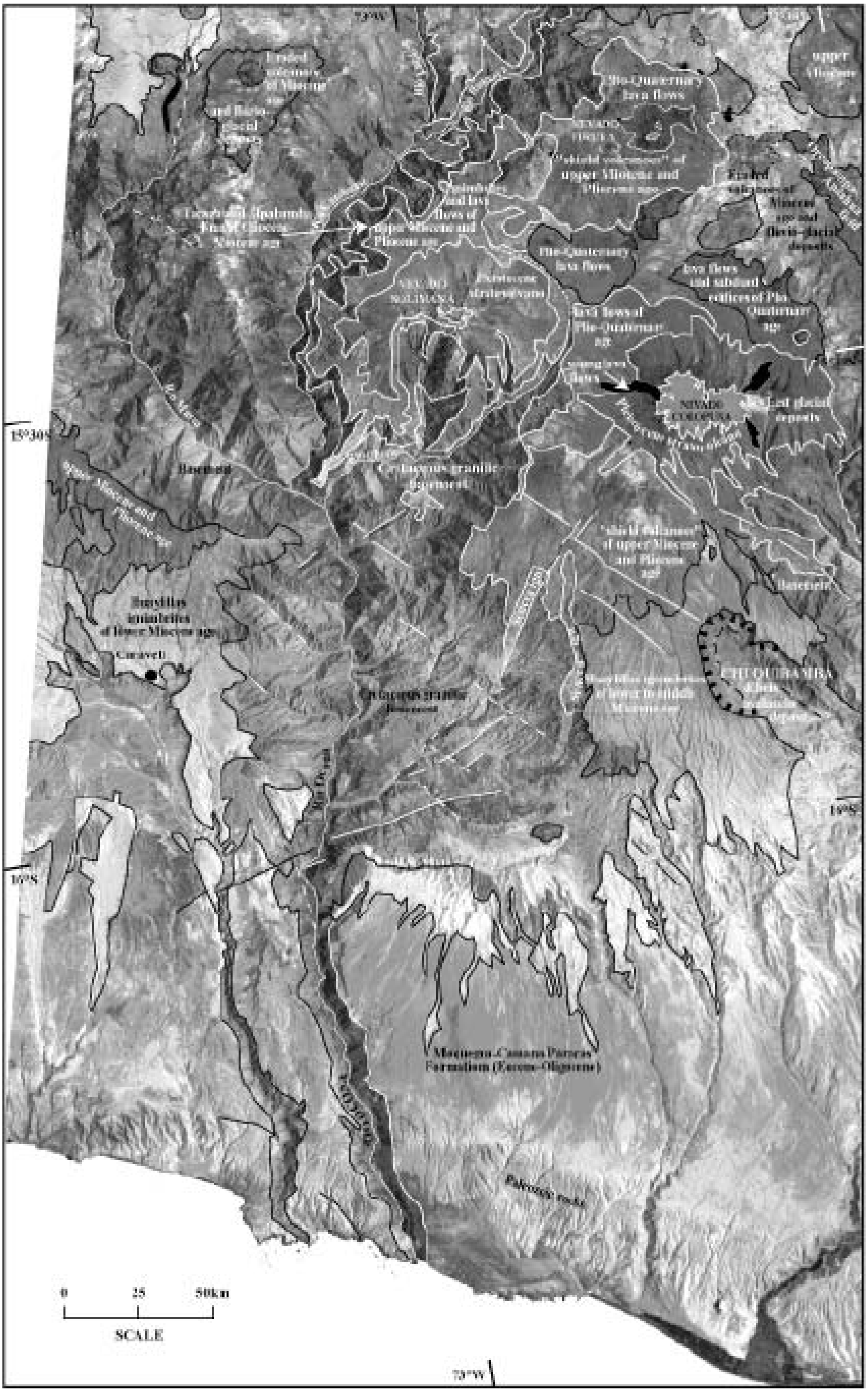

Fig. 1 showing the area of the canyons of Rio Ocoña and Rio Cotahuasi in the Western Cordillera, ignimbrites, and three types of volcanoes. Main geologic units and faults are also shown.

Marine sediments and conglomerates of Eogene age are uplifted to as much as 2000 m asl. in the area of Caraveli and on the east side of the Rio Ocoña (Fig. 3). The main palaeosurface, which has been mantled by the Huaylillas ignimbrites of lower Miocene age, is tilted and ist eastern parts uplifted from about 2500 m to 4000 m asl. in the area of Chuquibamba (Fig. 3). More than half of the uplift (about 2000 m) of the Western Cordillera postdates the emplacement of the Huaylillas ignimbrites (Kennan, 1999). This uplift, combined with the increase of water discharge from glacial sources since Upper Pliocene times triggered the downcutting by at least 1500 m of the Ocoña, Cotahuasi and Colca Canyons since the middle Miocene to Pliocene. Further downcutting of the canyon occured after the emplacement and infilling of the Pliocene lava flows and ignimbrites

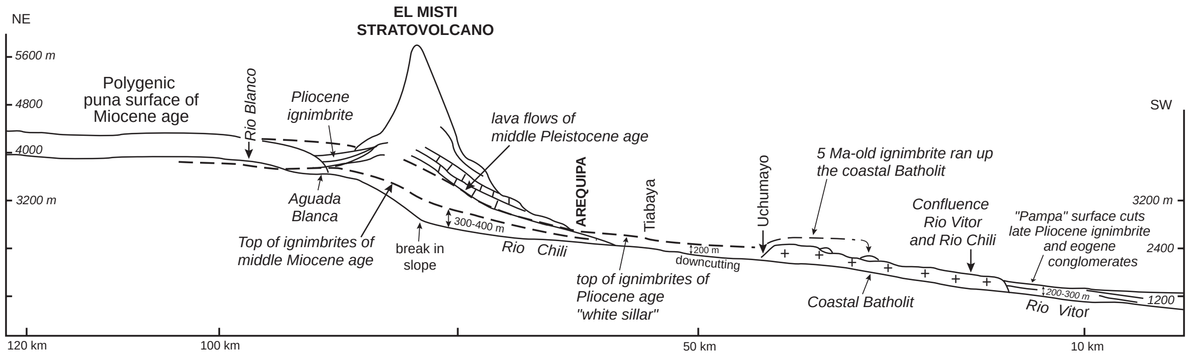

Fig. 2 showing the Rio Chili valley through the Western Cordillera and the depression of Arequipa, El Misti stratovolcano and three groups of ignimbrites (middle Miocene, Pliocene, and early Pleistocene). The amount of uplift and downcutting is estimated using the Miocene surface remnants and the base of ignimbrites and lava flows.

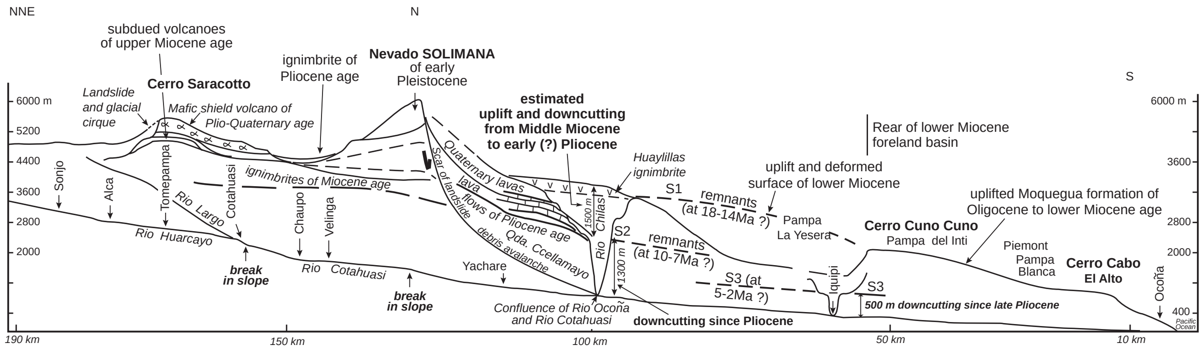

Fig. 3 showing the canyons of the Rio Ocona and Cotahuasi through the western Cordillera, three groups of volcanoes (upper Miocene, Plio-Quaternary, and Pleistocene in age), and three groups of ignimbrites (Alpabamba, Huaylillas, and Sencca) . The amount of uplift and downcutting is estimated using the S1, S2, and S3 surface remnants.

CONCLUSIONS

Digital elevation model (DEM) based on six digitized topographic maps (1:250.000) will be used to illustrate the relationships between the generations of ignimbrites and volcanoes, the uplift of the surface remnants and the downcutting of the canyons. The rapid rate of uplift of the western Cordillera and the distinct rate of the downcutting in the deep Rio Ocoña canyon versus that of Rio Chili are inferred from calculations using the DEM and Ar-Ar geochronology on volcanic rocks.

Downcutting of the deepest canyons on Earth has triggered huge landslides. Collapses involved the Miocene ignimbrites that form the highest canyons walls, e.g., above the town of Cotahuasi, and the edge of the

Huaylillas plateau near Chuquibamba (Fig. 3). Downcutting also triggered flank failures on the Plio-Quaternary volcanoes, such as the southwest flank of Nevado Solimana. Subsequent debris avalanches have dammed the upper course of Rios Cotahuasi and Rio Huarcaya in Pleistocene time. Downcutting continues and valley flanc and volcano instabilites pose a major hazard in these ultr-deep canyons. Further hazards are also related to potential dam breakouts that may trigger devastating debris flows toward the populated lower valleys.

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