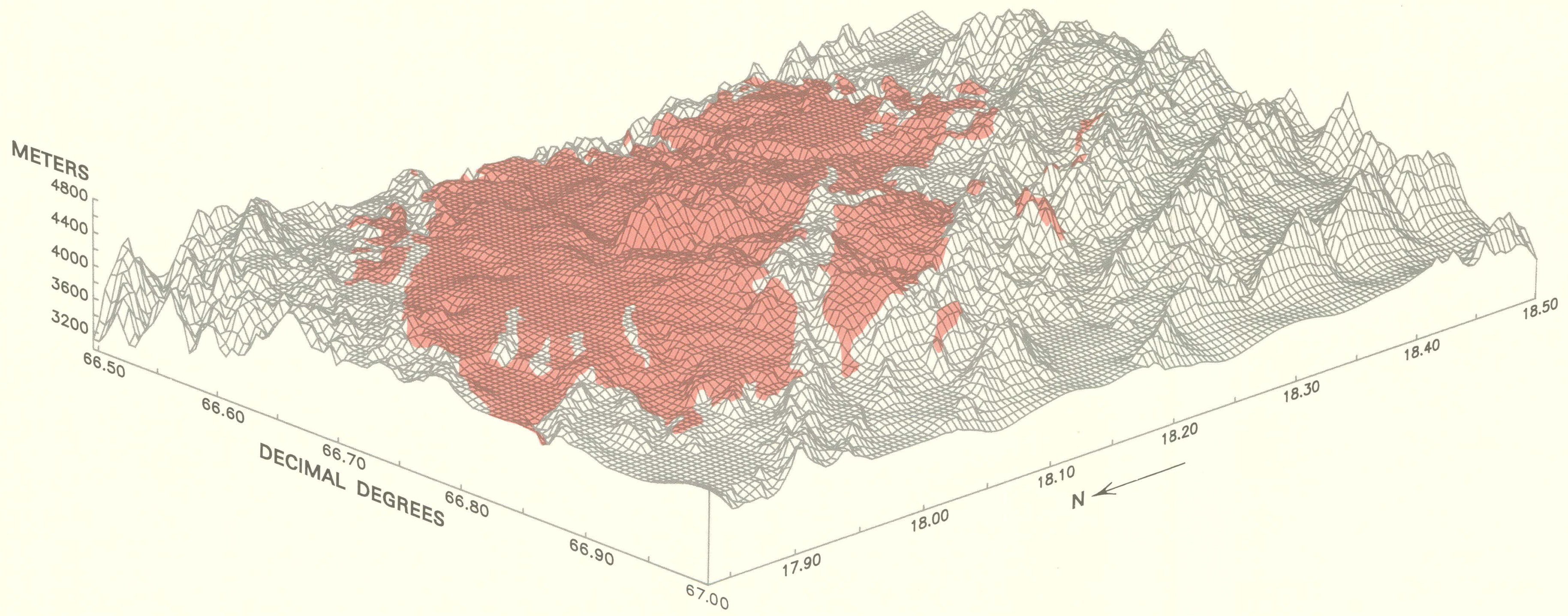
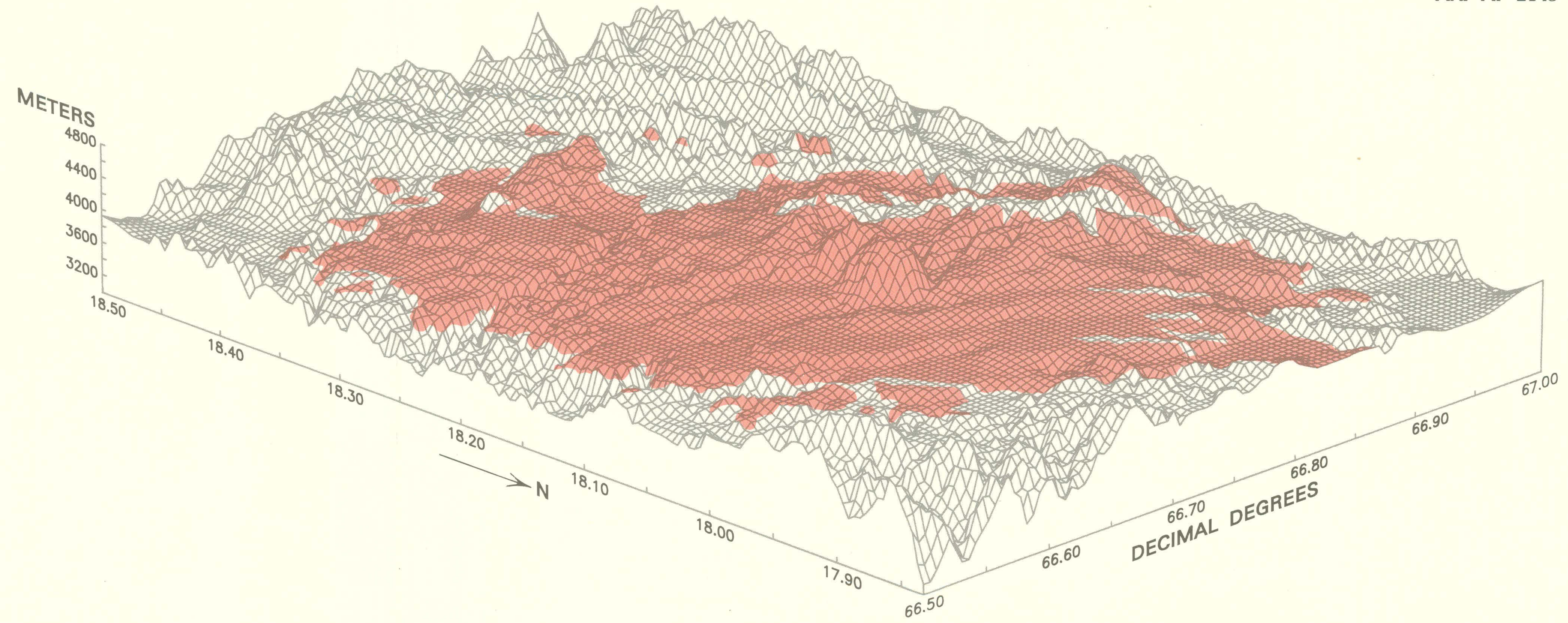


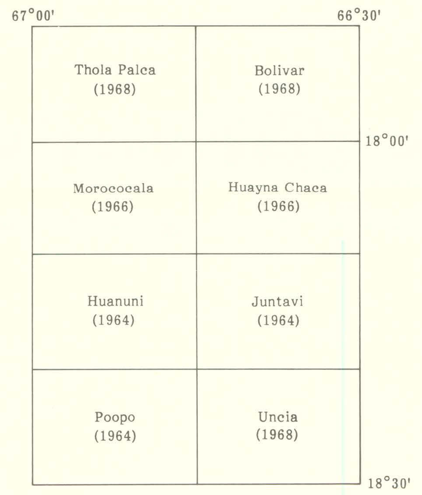
← VIEW FROM NORTHWEST

This view from the northwest shows the gently rolling surface of the volcanic field (shaded) north, east, and south of the prominent twin-peaked resurgent Tankha Tankha caldera. Several windows in the northern part of the volcanic field expose the underlying country rock, which evidently had a surface of gentle to moderate relief at the time the Morococala tuffs were erupted. However, on the northeastern (left) and southwestern (right) edges of the volcanic field, and particularly along the so-called Santa Fe ridge (the larger prominent prong of exposed country rock within but near the western edge of the volcanic field), visible relief on the old erosion surface is extreme and variable thicknesses of the volcanic cover are indicated; between the Santa Fe ridge and the western edge of the field, the welded tuff fills an ancient valley to a depth of more than 500 meters. Strikingly featured in this view is the northwest-trending valley and ridge topography, peripheral to the volcanic plateau, formed by erosion of the intensely folded and faulted, chiefly lower Paleozoic, country rocks.

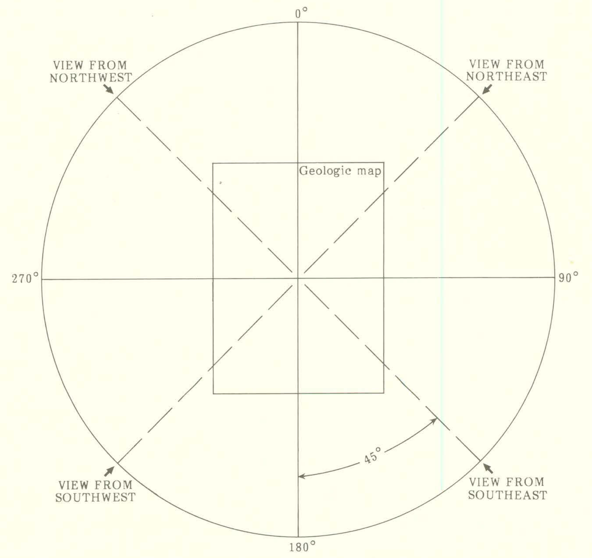
VIEW FROM NORTHEAST →

This view from the northeast shows the dimensional extent of the volcanic field, topographic relief on the volcanic ash-flow tuff surface (shaded), and the prominent resurgent dome within the Tankha Tankha caldera. Thicknesses of the volcanic cover, estimated from exposures in cliff edges along the east side of the field and from exposures at the merge (onlap) of the window of country rocks in the west, range from zero to several hundreds of meters. The extent and estimated thicknesses of the volcanic cover, and its topographic expression, indicate the underlying surface to have a relatively gentle to moderate topographic relief. This suggested relief is perhaps due to a thin inlier of redbeds, of Late Cretaceous and early Tertiary age, filling and smoothing out the eroded surface on the older lower Paleozoic country rock. To judge from the isolated erosional remnants of the older rhyolitic tuff south of, and the younger quartz latitic tuff northeast of the main volcanic field, the Morococala plateau formerly covered an area 50 to 100 percent greater than the presently exposed area.

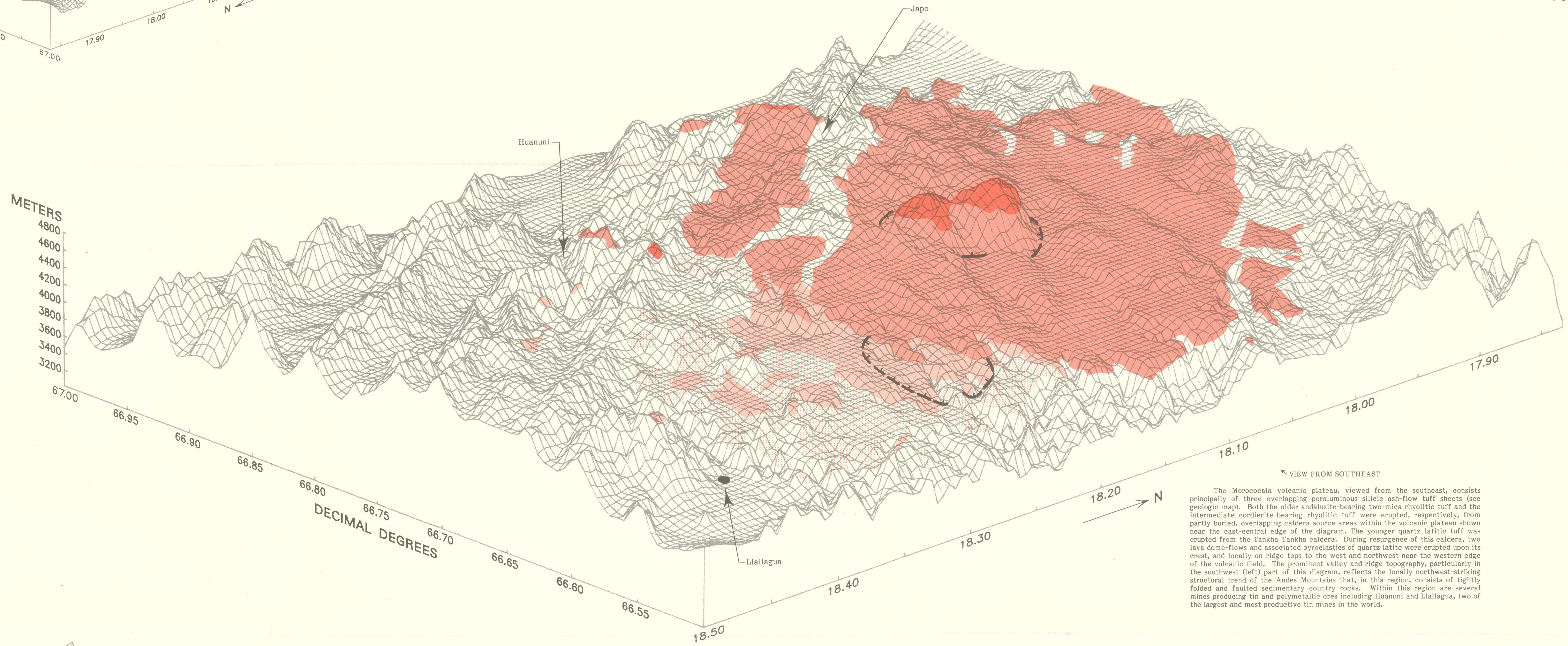




Index map showing Army Map Service 1:50,000-scale topographic quadrangles used to construct the perspective diagrams.



Index diagram showing angle of view for each perspective



↖ VIEW FROM SOUTHEAST

The Morococala volcanic plateau, viewed from the southeast, consists principally of three overlapping peraluminous silicic ash-flow tuff sheets (see geologic map). Both the older andalusite-bearing two-mica rhyolitic tuff and the intermediate cordierite-bearing rhyolitic tuff were erupted, respectively, from partly buried, overlapping caldera source areas within the volcanic plateau shown near the east-central edge of the diagram. The younger quartz latitic tuff was erupted from the Tankha Tankha caldera. During resurgence of this caldera, two lava dome-flows and associated pyroclastics of quartz latite were erupted upon its crest, and locally on ridge tops to the west and northwest near the western edge of the volcanic field. The prominent valley and ridge topography, particularly in the southwest (left) part of this diagram, reflects the locally northwest-striking structural trend of the Andes Mountains that, in this region, consists of tightly folded and faulted sedimentary country rocks. Within this region are several mines producing tin and polymetallic ores including Huanuni and Llallagua, two of the largest and most productive tin mines in the world.

EXPLANATION

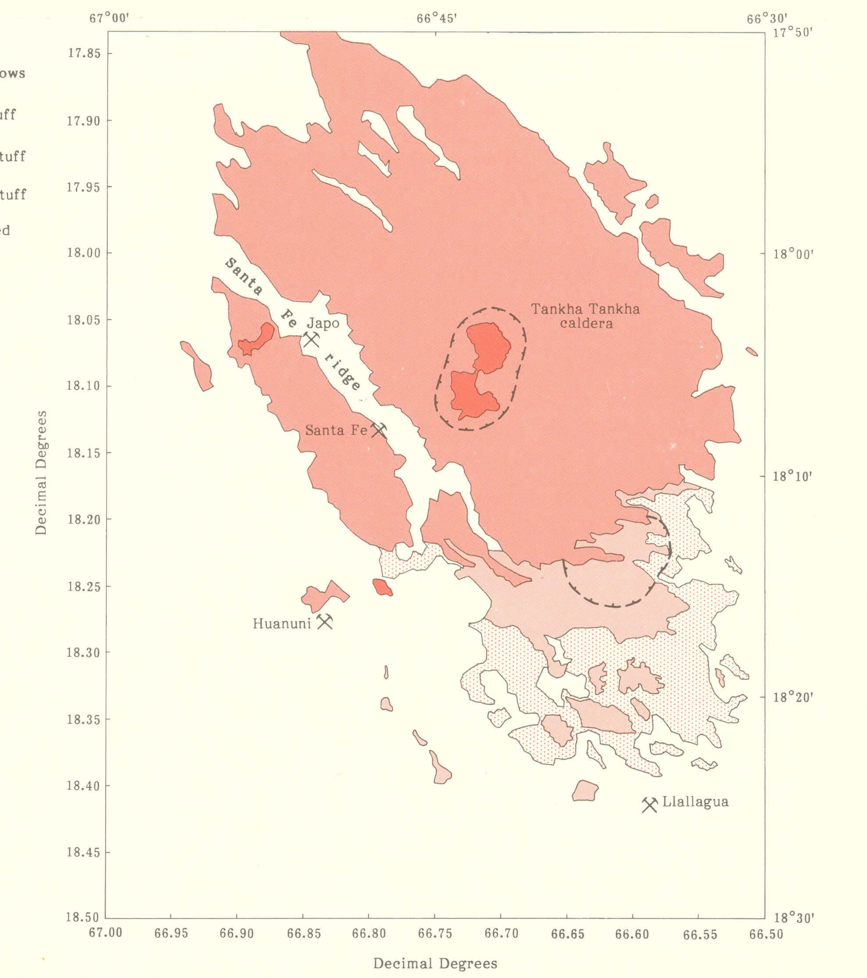
Volcanic rocks (Younger to Older):
- Quartz latite flows
- Quartz latite tuff
- Upper rhyolite tuff
- Lower rhyolite tuff

Undifferentiated country rocks

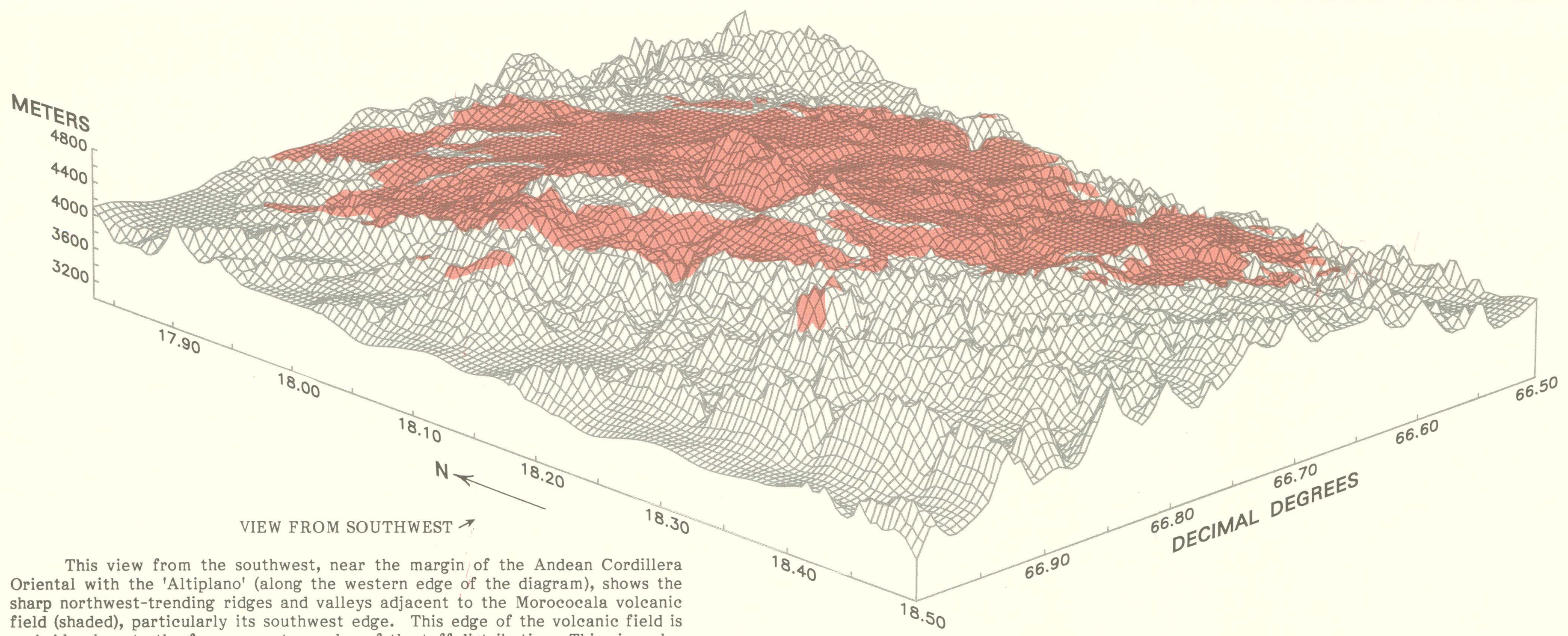
⚒ Principal mines

— Caldera outline

0 — 10 KM



Digital geologic map of the Morococala volcanic field, west-central Bolivia. Geology from Luedke and others (1990).



VIEW FROM SOUTHWEST ↗

This view from the southwest, near the margin of the Andean Cordillera Oriental with the 'Altiplano' (along the western edge of the diagram), shows the sharp northwest-trending ridges and valleys adjacent to the Morococala volcanic field (shaded), particularly its southwest edge. This edge of the volcanic field is probably close to the former western edge of the tuff distribution. This view also shows the current (1990) dimensional extent, approximately 40 km wide and 85 km long, of the volcanic field.

DISCUSSION

The application of computer systems to generate and display geologic information, particularly three-dimensional models that aid in the visualization and analysis of geologic features in the Earth's crust, is becoming more commonplace as the usefulness of these digital methods become known. Rapid developments in the capabilities of computer hardware and the evolution of "user friendly" software has enhanced the availability of this technology to an ever increasing number of geoscientists.

The computer-generated three-dimensional perspective diagrams shown here, are of a small area within the Cordillera de los Andes of west-central Bolivia (index map of Bolivia). These diagrams show variously oriented perspectives (see index diagram) of the Morococala meseta, a volcanic plateau which extends over an area of about 1500 km^2 in the central and most productive part of the Bolivian tin belt. This volcanic field is of particular interest because (1) it contains rare tin-rich, peraluminous, two-mica, andalusite- and cordierite-bearing ash-flow tuffs, and (2) the volcanic rocks, which are chiefly of late Miocene age, cover a basement of lower Paleozoic, upper Mesozoic, and lower Cenozoic sedimentary rocks that contain the early and middle Miocene, altered, sub-volcanic porphyritic intrusive masses and associated tin deposits in this part of the tin belt. As indicated on the geologic map, some of these tin deposits (Llallagua and Huanuni being among the largest and most productive of Bolivian tin deposits) are marginal to the volcanic field. It is likely that similar deposits exist in the older rocks beneath the volcanic cover (Ericksen and others, 1990).

The Morococala volcanic field consists of three major, overlapping, but separate, ash-flow tuff sheets and a minor group of lava dome-flow complexes (see geologic map). These volcanic units consist of peraluminous silicic rocks 6-8 Ma in age (Koeppen and others, 1987) that unconformably overlie a basement composed of predominantly lower Paleozoic, locally metamorphosed, shale containing siltstone and sandstone layers. The basement-rock sequence has been structurally deformed into a series of tight to isoclinal, locally overturned, folds aligned with the prominent northwest-striking regional structural grain of the Andean Cordillera Oriental, and broken by many steeply-dipping normal and reverse faults (United Nations, 1982, unpublished map). The two older rhyolitic tuff units probably erupted from two, partly buried, overlapping calderas in the southeastern part of the volcanic field (see geologic map). The younger quartz latitic tuff unit erupted to form a third caldera (Tankha Tankha) in the north-central part of the field; this caldera contains a prominent twin-peaked resurgent structure, capped by two quartz latitic lava dome-flows and associated pyroclastics.

The base material used in the preparation of these diagrams included eight topographic quadrangles (see index map of quadrangles) at a scale of 1:50,000, mosaicked and reduced into a composite base map at a scale of 1:100,000. The geology is from Luedke and others (1990).

The proceedures used to develop the computer-generated three-dimensional perspective (mesh) diagrams for this study involved several steps. Because no digital elevation data previously existed for either the topography or geology of this area, the necessary information was hand digitized using GSMAP (Selner and Taylor, 1988) to encode both the topographic index contour lines and the geologic contacts at a scale of 1:100,000. The digital information from these two data sets was then processed and displayed using Interactive Surface Modelling (ISM) software. A minimum tension grid of 150 rows by 100 columns was computed by using a biharmonic cubic spline function to fit a surface to the topography; this method honors all data points and minimizes the sum of the square errors (Dynamic Graphics, 1988). The resulting diagram is a best fit of the simplified geologic map draped over the computed surface topography for graphic presentation. Each perspective diagram displays the same area viewed at an inclination of 20 degrees from the horizontal plane and rotated in 90-degree increments (see angle of view index diagram).

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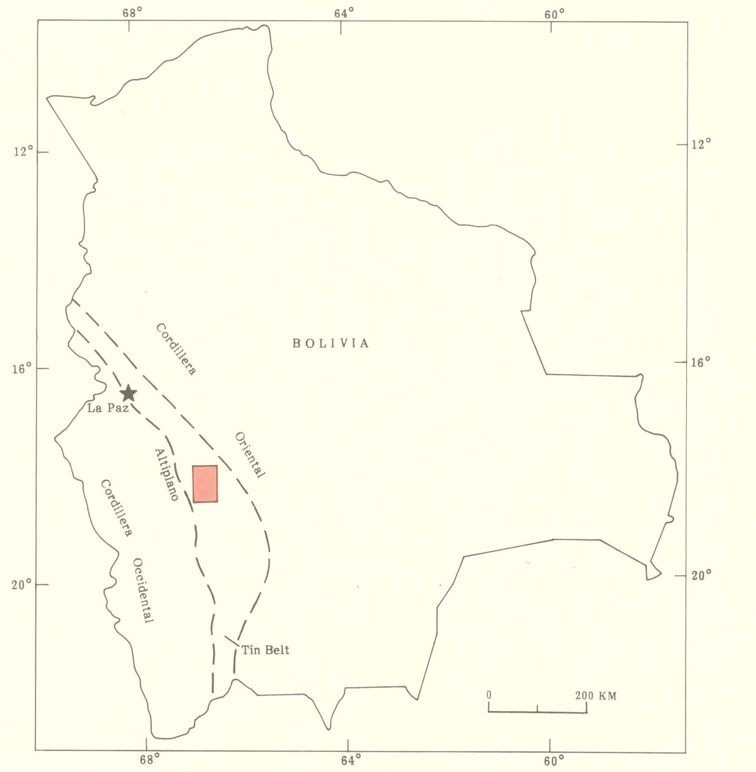

Index map showing location of study area (shaded).

THREE-DIMENSIONAL PERSPECTIVE DIAGRAMS OF THE MOROCOCALA VOLCANIC FIELD, WEST-CENTRAL BOLIVIA

By
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