ANDEAN MAGMATISM AND METALLOGENY

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SUMMARY

The Historic and Holocene volcanoes of the Central Volcanic zone form a 1,500 km long and 50 km wide belt. It is followed to the N and S by non-volcanic zones. Three Holocene volcanoes occur 125-225 kms E of the main volcanic belt.

The present non-volcanic zones formed mostly during the past 5 m.y. During the past 570 m.y. there were two distinct parallel magmatic-hydrothermal belts, separated 125-400 kms. Both had temporary non-magmatic stretches. Historic and Holocene volcanism suggests that magmatic activity may have alternated between these belts over periods of less than 10,000 years.

South of 18°S the magmatic belts moved mainly from E to W between 570 and 115 m.y., and from W to E thereafter. North of 18°S these belts moved mainly from W to E during the past 570 m.y., but there were temporary reversals of these trends.

A vast majority of the igneous rock types occurs in both magmatic belts, but in different proportions.

The Central Andes had a single mega-metallogenic epoch (Cambrian to Present) with two mega-metallogenic provinces corresponding to the two magmatic belts. Each mega-metallogenic province consists of sub-provinces defined by major ore-forming environments. Ore deposits are more common where the magmatic belts resided most of the time.

INTRODUCTION

Fig. 1 shows that the Historic and Holocene volcanoes of the Central Volcanic Zone of the Andes form a belt that is about 1,500 kms long (15° - 27° S) and 50 kms wide. It is 250-400 kms E of the Perú-Chile trench and is followed both to the N (2-15°S) and S (27-34°S) by non-volcanic zones. This volcanic belt is relatively straight in Perú, but sinuous and occasionally 100-150 kms wide along the borders of Chile and Bolivia and Argentina. In addition, there are three Holocene volcanoes 125-225 kms E of the main volcanic belt.

Over 1,800 radiometric age dates were plotted for 24 time intervals on 1:5,000,000 scale maps in order to determine the location of magmatism and hydrothermal activity from the Cambrian to the Present (Petersen 1999). Figs. 1-8 show these plots complemented with additional data from McBride et al. (1976).

MAGMATIC BELTS AND NON-MAGMATIC ZONES

Figs. 2 and 3 show that the present non-volcanic zones formed mostly during the past 5 m.y. Figs. 2 to 8 show that during the past 570 m.y. there were generally two distinct and essentially parallel magmatic-hydrothermal belts separated 125-400 kms. Both had non-magmatic stretches during some time intervals.

For periods greater than 1 m.y. the main magmatic arc and the back-arc often appear to have been active simultaneously. However, a review of Historic and Holocene volcanism around the Pacific Ocean suggests that magmatic activity along the magmatic belts may have alternated over periods of less than 10,000 years. Such oscillations may reflect alternating stress patterns in the continental plate.

South of 18°S the magmatic belts moved mainly from E to W between 570 m.y. and 115 m.y., and from W to E thereafter. North of 18°S these belts moved mainly from W to E during the past 570 m.y. Temporary reversals of these trends may be due to occasional changes in the dip of the subducting plate, but their dominant W to E movement since 115 m.y. could be due to ablation of the prow of the continental plate.

Abrupt displacements of segments of the main magmatic belt (Figs. 6 and 7) suggest tearing of the subducted Nazca plate or later faulting of the continental plate. Local widenings of and alignments within the main magmatic belt (Fig. 1) may reflect transverse fracture zones in the continental plate. Sinuosities of the magmatic belts (Figs. 1-8) may indicate undulations in the subducting plate. Only very few data points do not fit this general model. The greater scatter of points on Fig. 8 results from having plotted a much larger time interval than in the other figures. W to E hot-spot trails, like in the western U.S.A., are not evident.

MAGMA COMPOSITIONS

A statistical evaluation of dated igneous rock compositions indicates that a vast majority of the rock types occurs in both magmatic belts, but in different proportions. Phonolites and nepheline syenites appear to be confined to the back-arc, but constitute only 0.3% of all rocks; 94.5%

are intermediate or felsic, and 5.1% are mafic. Alkalic and siliceous rocks are more common in the back-arc, whereas intermediate and calcalkaline rocks predominate in the main arc.

METALLOGENY

In general terms, it appears that in the Central Andes there was a single hydrothermal mega-metallogenic epoch (from the Cambrian to the Present), which gave rise to two hydrothermal mega-metallogenic provinces (corresponding to the two magmatic belts). Each hydrothermal mega-metallogenic province consists of sub-provinces defined by major hydrothermal ore-forming environments. For example, veins, orebodies and disseminations of Cu, Pb, Zn, Ag and Au (both high and low sulfidation) occur in higher portions of both magmatic belts. Disseminated ("porphyry") deposits are mostly in deeper portions of the main belt, but also in deeper portions of the back-arc. Volcanogenic massive sulfide deposits are restricted to the main magmatic belt, probably because its western positions were often submarine. Skarn and replacement deposits predominate in the Peruvian sector of the main magmatic belt, perhaps because in Perú the stratigraphic column contains a higher proportion of limestone where the main belt was located more recently. But there are also some skarn deposits in the back-arc. Sn-W deposits appear to be restricted to the back-arc, perhaps because they are related to specialized magmatic compositions or to thick shale sequences.

Hydrothermal ore deposits are more common where the magmatic belts resided most of the time, and fewer in regions invaded only temporarily by the magmatic belts (i.e., between and both E and W of the areas occupied most of the time by the magmatic belts). Past mineral exploration covered the entire length of the main magmatic belt. The back-arc was explored mostly in Bolivia, in southeastern Perú and in Argentina. Future mineral exploration may focus more on the eastern slopes of the Andes in Argentina and Perú.

CONCLUSIONS

The evidence presented in this paper and the geological and paleogeographic evidence put forth by Scotese (1987) make a compelling case for subduction, magmatism and hydrothermal ore deposition along the western margin of South America since the Cambrian, 570 m.y. ago. It is clear that two parallel magmatic-hydrothermal (and possibly metamorphic) belts were generally active, but probably alternating over rather short time intervals (say within less than 10,000 years). The general parallelism of both magmatic belts suggests that they resulted from coupled or related processes (such as alternating compressive and tensional stresses caused by variations in the rates of convergence of the oceanic and continental plates).

Further research should extend this study to the northern and southern Andes, as well as to the Northamerican Cordillera and the Appalachians in order to test the general validity of these results and their implications for orogeny, metallogeny and mineral exploration.

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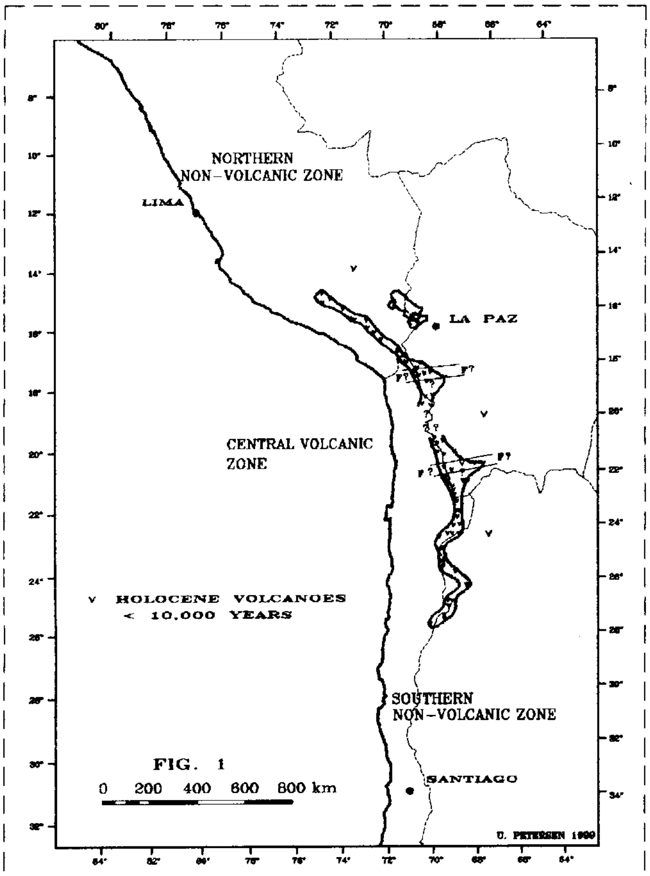


FIG. 1

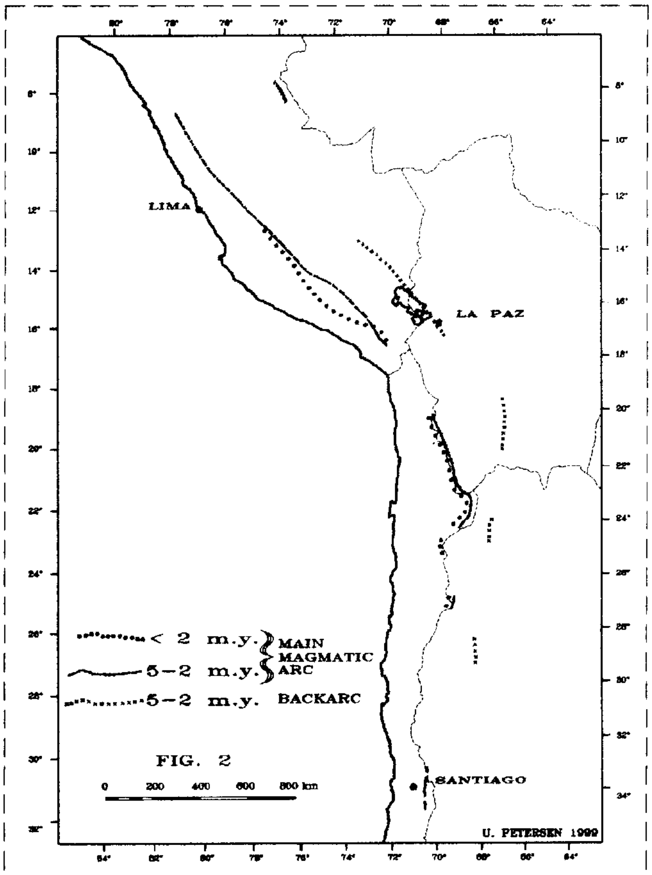
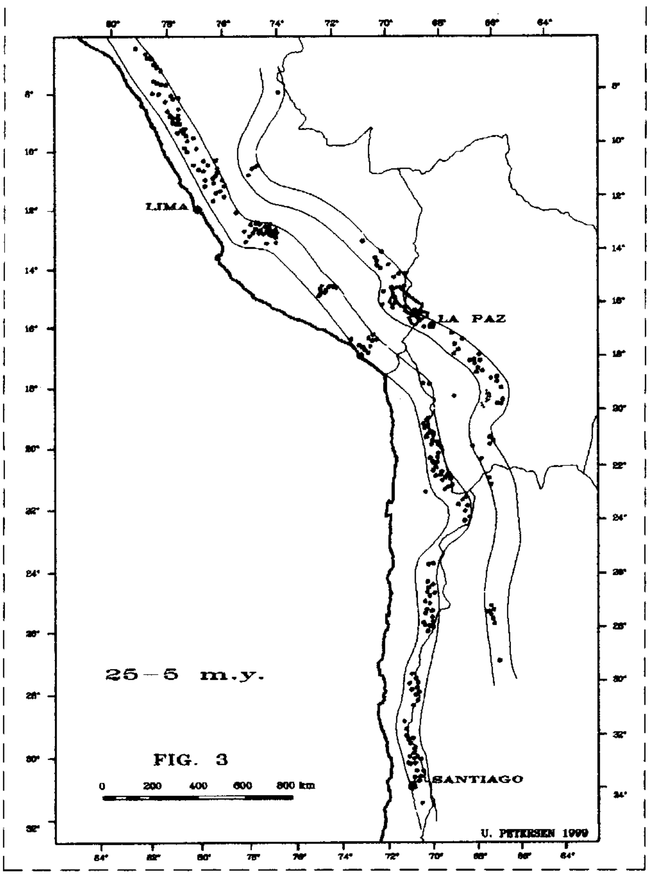


FIG. 2



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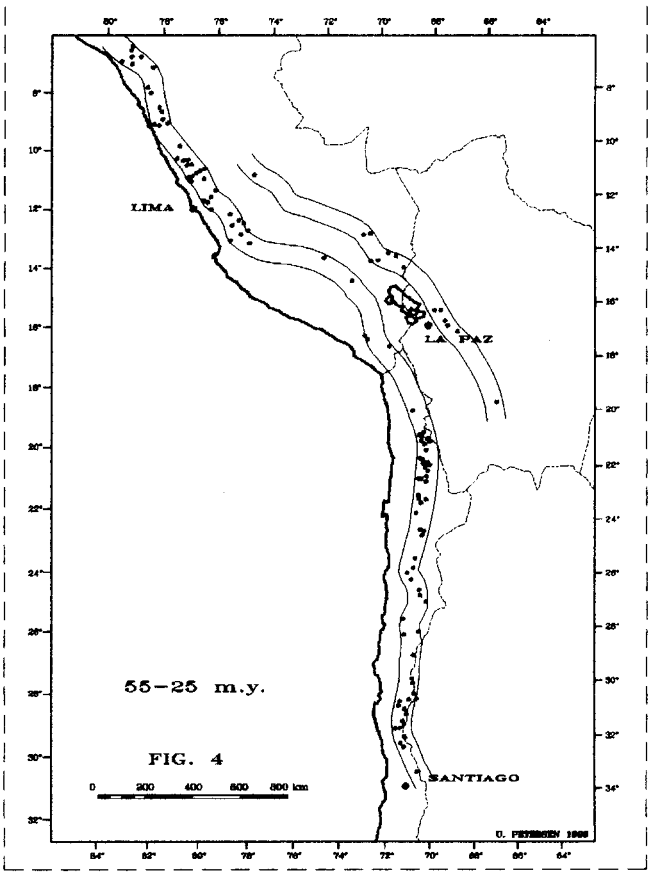

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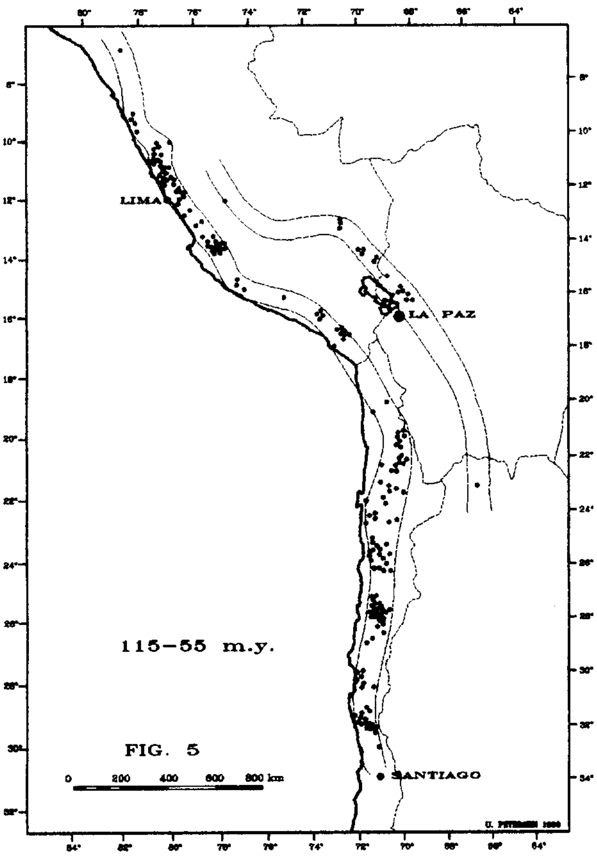

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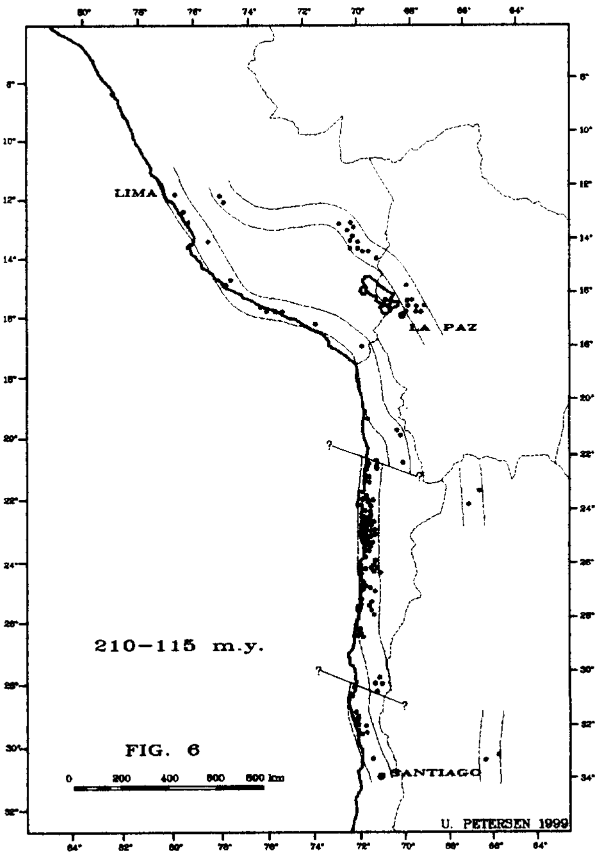

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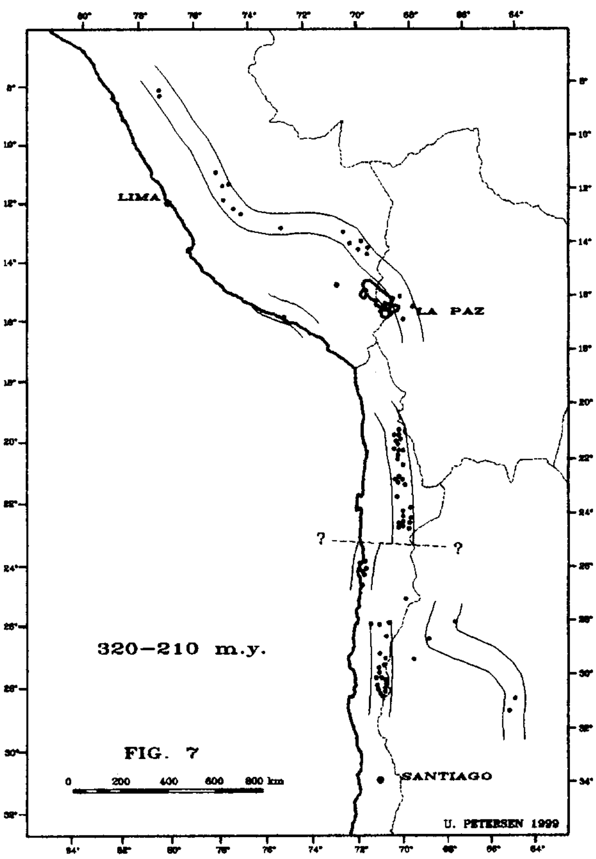

FIG. 7

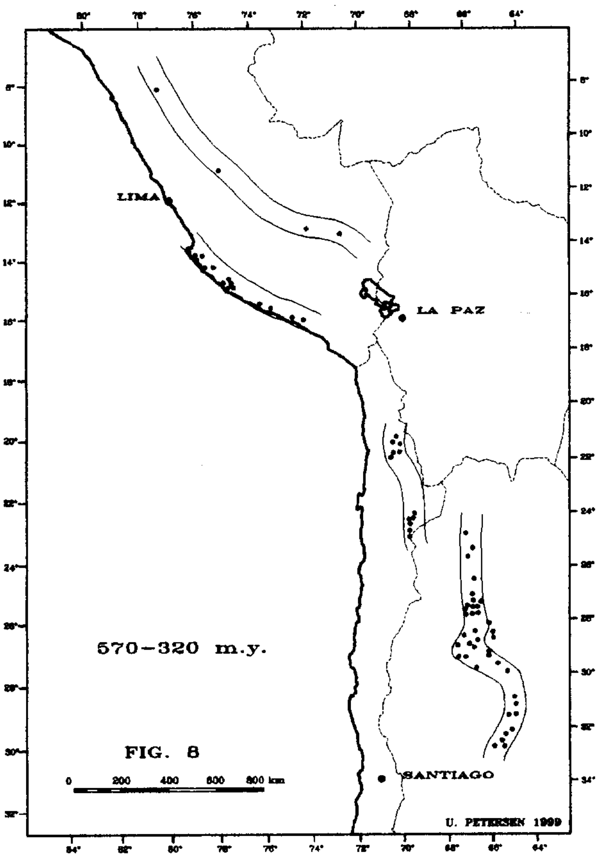

FIG. 8