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Rb-Sr AGES OF METAMORPHIC ROCKS FROM THE TARMA AREA OF THE CENTRAL ANDEAN CORDILLERA, CENTRAL PERU

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The metamorphic rocks regarded as Precambrian are widely exposed in the Tarma area of the central cordillera, central Peru.

Discordant Rb-Sr ages of 230 and 147 m.y. on biotite were obtained from a sillimanite-biotite migmatitic gneiss and a garnet porphyrobast biotite schist, respectively, in the metamorphic mass of the area. The presence of the retrogressive imprint observed in the gneiss suggests that the older age is a minimum one of the regional metamorphism in the area. It also suggests that a main phase of its metamorphism belongs to an upper Paleozoic orogeny revealed by Rb-Sr whole-isochron ages from a Chilean metamorphic basement.

The younger age might indicate the effect of a late Jurassic-early Cretaceous plutonic mass or a tectonic event of this time.

INTRODUCTION

In Peru, Precambrian rocks have been considered to be exposed in the central Andean cordillera and along the southern Peruvian coast as shown in Fig. 1 (Mapa Geologico del Peru, 1975).

Many age determinations have been carried out on the Precambrian crystalline rocks from the southern coast (Stewart *et al.*, 1974; Cobbing *et al.*, 1977; Dalmayrac *et al.*, 1977). Their ages range from Precambrian, 2,000–1,800 m.y. on the granulite-facies rocks, to Tertiary and suggest that the coastal basement has complex history. The geochronology and petrology of the central Precambrian rocks are not yet developed.

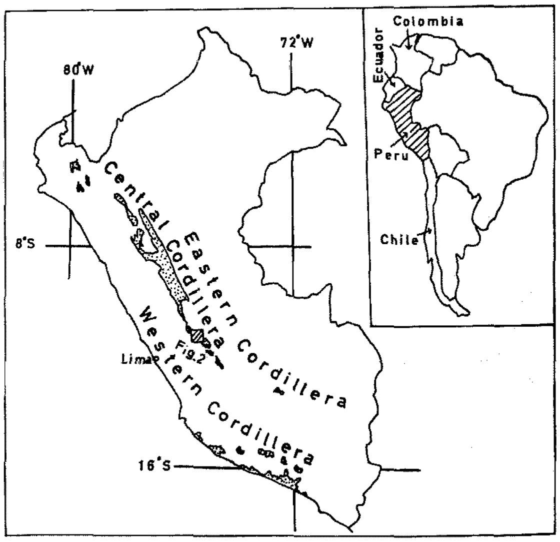

Fig. 1. Map showing the general location of Precambrian rocks (dotted area) in Peru (after Mapa Geologico del Peru, 1975).

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The Tarma area, where the metamorphic complex regarded as Precambrian is widely exposed, is situated in the central Andean cordillera.

This paper reports Rb-Sr ages on the metamorphic rocks of the central cordillera basement in the Tarma area of central Peru along with some discussions on the metamorphism of the area.

Samples described in this paper were collected during the Andes Scientific Expedition conducted in 1977 by Shizuoka University.

GEOLOGICAL AND PETROLOGICAL OUTLINE

Tarma area is made up of metamorphic, igneous and sedimentary rocks (Fig. 2). The metamorphic rocks are intruded by three kinds of plutonic rocks regarded as Paleozoic, Paleozoic-Mesozoic and Tertiary (Mapa Geologico del Peru, 1975) and consist of three masses—western, central and eastern.

The central mass consists of schists characterized by assemblages of calcite-chlorite-actinolite-epidote-plagioclase or chlorite-muscovite-plagioclase-quartz, and is intruded by three kinds of plutonic rocks.

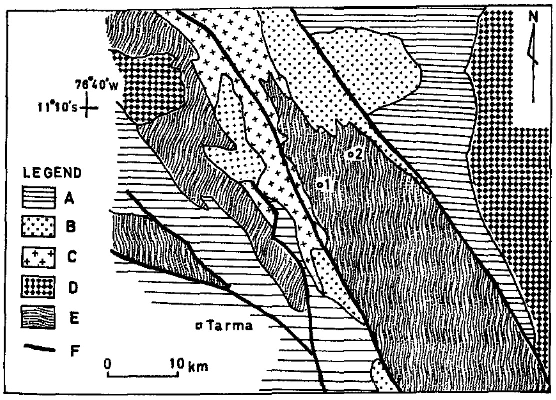

Fig. 2. Geologic map of the Tarma area (after Mapa Geologico del Peru, 1975). A: Sedimentary rocks, B: Tertiary plutonic rocks, C: Paleozoic-Mesozoic plutonic rocks, D: Paleozoic plutonic rocks, E: Metamorphic rocks, F: Faults, 1 and 2: Sample locations.

The eastern mass consists of schists and gneisses which are intruded by Paleozoic and Paleozoic-Mesozoic plutonic rocks. The grain size increases toward the east, and schists have changed to migmatitic gneisses. The schists are characterized by an assemblage of garnet-muscovite-biotite-plagioclase-quartz and gneisses by that of cordierite-sillimanite-biotite-orthoclase-plagioclase-quartz.

The grain size and metamorphic grade of the metamorphic rocks increase toward the east. The schists in the central mass belong to the greenschists facies, the medium-coarse grained schists in the western part of the eastern mass to the amphibolite facies, and the gneisses in its central and eastern part to a high-temperature part of the amphibolite facies.

The schists and gneisses have the imprint of the later retrogressive metamorphism, such as wavy extinction of quartz, pinitization of cordierite, sericite aggregate after sillimanite and secondary chlorite filling the cracks.

SAMPLE DESCRIPTIONS

Two samples in the eastern metamorphic mass were selected for Rb-Sr radiometric dating; one was a garnet porphyroblast biotite schist (1 in Fig. 2) and the other a sillimanite-biotite gneiss (2 in Fig. 2).

The schist is composed of quartz, plagioclase, muscovite, biotite, garnet and opaque mineral with secondary chlorite. The Z-axial color of biotite is brown or reddish brown. The later retrogressive metamorphism is marked by the following imprint:

The wavy extinction of quartz, distorted plagioclase-twin, the alteration of plagioclase and marginal part of garnet, and chlorite filling the cracks.

The gneiss forms the melanocratic part of migmatitic gniess and is composed of quartz, plagioclase, biotite, orthoclase, sillimanite and opaque mineral with secondary chlorite. The Z-axial color of biotite is reddish brown and sillimanite is mostly fibrous. The later retrogressive metamorphism is marked by the following imprint: the wavy extinction of quartz, distorted plagioclase-twin, some sericitized sillimanite and altered plagioclase.

The secondary chlorite is more abundant in the schist than that in the gneiss.

RADIOMETRIC AGE DETERMINATIONS

Two biotite samples from the metamorphic rocks were analyzed for Rb-Sr age determinations. Analytical procedures used in the present study were as follows; Rb and Sr concentrations were determined by isotope dilution method using ^{87}Rb and ^{84}Sr spikes. ^{87}Sr/^{86}Sr ratios were calculated from spiked runs. Isotopic analyses were made using a 60 sector, 22 cm radius single focusing mass spectrometer with an electron multiplier. The single tantalum filaments method was employed. To monitor experimental precision, replicate analyses of such standards as P–207 muscovite were performed periodically. Analytical uncertainty in ^{87}Sr/^{86}Sr ratios is assumed to be $\pm 0.1\%$. The uncertainty in ^{87}Rb/^{86}Sr ratios is considered to be less than 2%. An initial ^{87}Sr/^{86}Sr ratio of 0.708 is assumed for the age calculations. Decay constant used is $\lambda_{87} = 1.39 \times 10^{-11}$ yr^{-1}.

The results are given in Table 1.

Table 1. Analytical data for the metamorphic rocks in the Tarma area of the central cordillera

Sample No.	Rock type	Mineral	Rb (ppm)	Sr (ppm)	^{87}Sr/^{86}Sr	^{87}Rb/^{86}Sr	Age (m.y.)
1 (77020204)	garnet-biotite schist	biotite	533.2	25.68	0.8351 ±0.0014	60.88	147
2 (77020207A)	sillimanite-biotite gneiss	biotite	530.1	26.97	0.9218 ±0.0008	65.37	230

DISCUSSION

The discordant Rb-Sr ages of 230 and 147 m.y. were obtained from the sillimanite-biotite migmatitic gneiss and the garnet-biotite schist in the Tarma area of the central cordillera, respectively.

Metamorphic rocks in the southern coast gave an U-Pb age of 2,000 m.y. and a Rb-Sr whole-rock isochron age of 1,800 m.y. on the granulite facies rocks (Cobbing *et al.*, 1977; Dalmayrac *et al.*, 1977). However, the mineral ages of the granulite facies rocks have yielded K-Ar ages ranging from 374 to 192 m.y., and the granitic rocks relating to migmatization of both the granulite facies rocks and the amphibolite facies rocks Rb-Sr ages of muscovite ranging from 341 to 224 m.y. (Cobbing *et al.*, 1977). A staurolite schist has been dated K-Ar ages of 210 m.y. on both biotite and muscovite, caused by the influence of granite intrusion (Stewart *et al.*, 1974). The older age obtained from the metamorphic rocks in the Tarma area is present in a range of these ages. These ages, ranging from Carboniferous to Triassic, have been reported abundantly from the metamorphic rocks in Chile and Colombia which are regarded as the continuation of Peruvian Andes metamorphic belt (Fig. 3), suggesting an orogeny of this time.

The gneiss as well as the schist marks the imprint of the later retrogressive metamorphism, and the schist in the same mass indicates a Jurassic age. Accordingly,

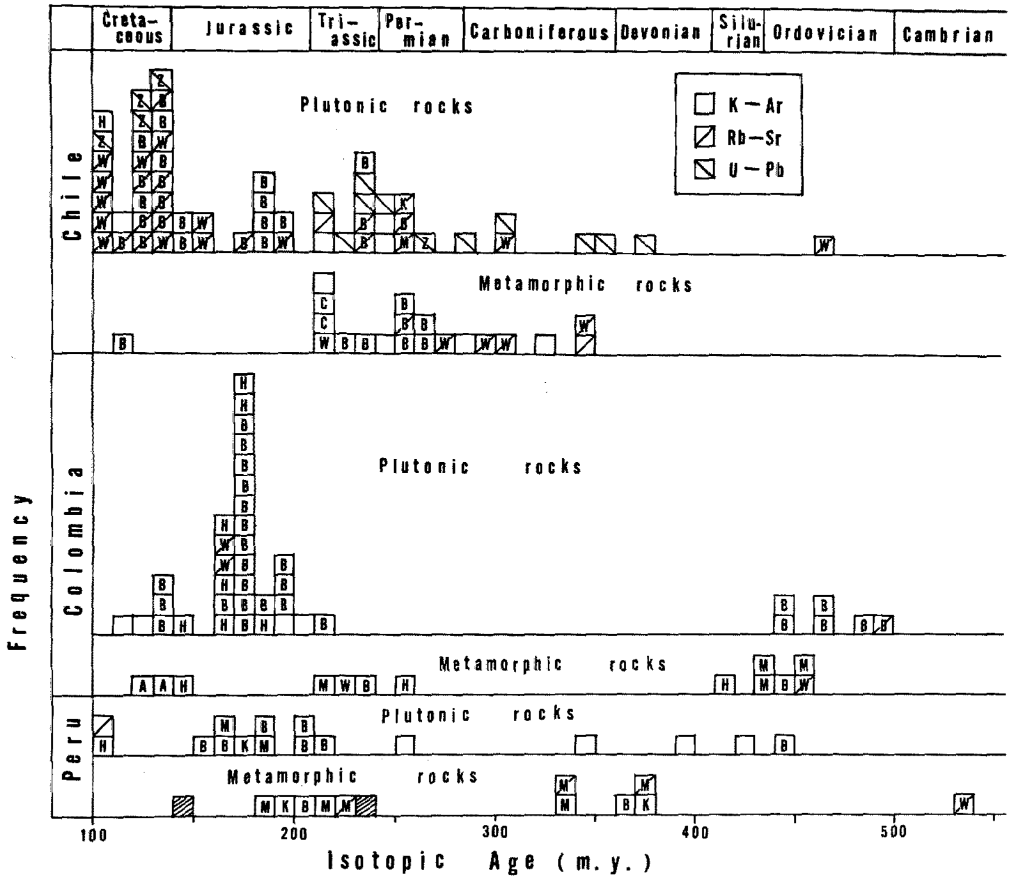

Fig. 3. Frequency distribution of isotopic ages for metamorphic and plutonic rocks from Colombia, Peru and Chile. These data are from Ruiz *et al.* (1961), Pinson *et al.* (1962), MacDonald and Hurley (1969), Farrar *et al.* (1970), González-Bonorino and Aguirre (1970), Goldsmith *et al.* (1971), MacDonald *et al.* (1971), Harpern (1973), Munizaga *et al.* (1973), Stewart *et al.* (1974), Tschanz *et al.* (1974), Irving (1975), MacBride *et al.* (1976) and Cobbing *et al.* (1977). Shaded data are based on the present study. Abbreviation: A=Amphibole, B=Biotite, C=Crossite, H=Hornblende, K=K-feldspar, M=Muscovite, W=Whole-rock isochron or whole rock, Z=Zircon.

the age obtained of 230 m.y. suggests a minimum one of the metamorphism. This idea is supported by the age of 210 m.y. from the staurolite schist influenced by late granite, and by Rb-Sr whole-rock isochron ages of 343 to 273 m.y. from the Chilean metamorphic basement (Munizaga *et al.*, 1973). The metamorphism of the migmatitic gneiss in the Tarma area is considered to belong to the upper Paleozoic orogeny regarded as producing the amphibolite facies rocks in Chile and Colombia (e.g. Munizaga *et al.*, 1973; Irving, 1975). The Precambrian basement on the southern coast also seems to have been subjected to this orogeny.

The schist in the same mass has been dated the age of 147 m.y. The schist exists near the Paleozoic-Mesozoic plutonic rock as shown in Fig. 2. The imprint of the retrogressive metamorphism, such as secondary chlorite, appears to be more conspicuous in the schist than that in the gneiss. These facts suggest that the age from the schist has resulted from the influence of the plutonic mass. In that case, the plutonic mass is inferred as Mesozoic, late Jurassic-early Cretaceous, and the migmatitic gneiss existing near the Tertiary plutonic mass hardly seems to have suffered from its effect.

In the southern coast and western cordillera the interval of intrusive rocks between late Jurassic and early Cretaceous has been pointed out by Stewart *et al.* (1974); they have reported that a foliated diorite has given a K-Ar age of **157** m.y. on biotite, which is the nearest plutonic age for that obtained from the schist. In northern Chile, these interval of the intrusive rocks has also recognized by Farrar and others (1970); they have reported that an altered granite has yielded a K-Ar age of **143** m.y. on biotite and hornblende. A Jurassic-Cretaceous orogeny of the Andes metamorphic belt is not yet recognized in Chile and Peru as shown in Fig. 3, but it is in the metamorphic rocks, belonging to the greenschist facies-amphibolite facies, of northern Colombia along the Caribbean Sea (MacDonald *et al.*, 1971; Tschanz *et al.*, 1974). The schist and the gneiss show the deformation texture. Therefore, the age obtained from the schist might indicate a tectonic event related to this orogney, suggesting that a fine-grained biotite has been more easily affected by the late effect as pointed out by Hart (1964) and others.

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ペルー，中央アンデス山脈のタルマ地域における変成岩の Rb-Sr 年代

藤吉　瞭・石坂　恭一・早瀬　一一

ペルー，中央山脈のタルマ地域には，先カンブリア紀と考えられている変成岩類が広く露出している。同地域の変成岩体中の珪線石・黒雲母ミグマタイト片麻岩および斑状変晶のざくろ石・黒雲母片岩は，それぞれ黒雲母で230 m.y. と 147 m.y. の異なる Rb-Sr 年代を示した。

片麻岩中に後退変成作用が観察されることから，得られた古い年代は，その地域の広域変成作用の最も新しい年代を示唆するとともに，同地域の広域変成作用のクライマックスは，チリの変成基盤岩からの全岩アイソクロン Rb-Sr 年代により解明された上部古生代であることを示唆している。

得られた若い年代は，ジュラ紀末期―白亜紀早期の深成岩体の影響か又はこの時期の構造運動に基づくものと思われる。