J. geol. Soc. London, Vol. **141**, 1984, pp. 877–884, 6 figs, 6 tables. Printed in Northern Ireland.

Rb-Sr isotopic ages from late Palaeozoic metamorphic rocks of central Chile

F. Hervé, K. Kawashita, F. Munizaga & M. Bassei

SUMMARY: Two metamorphic complexes of different lithology and structure crop out in the coast ranges of central Chile. The Tanumé metamorphics to the E, which belong to a low P/T series derived from a continental platform clastic sedimentary sequence, give a whole rock isochron age of 347 ± 32 (2σ) Ma and the accreted Pichilemu metamorphics to the W, an age of 311 ± 10 (2σ) Ma. The latter consist of stilpnomelane-bearing cherts, crossite-bearing metabasites and siliceous metapelites. An errorchron of *c.* 370 Ma was obtained from sillimanite–cordierite gneisses of the low P/T series. Different provenance of the protoliths is indicated by the higher Sr^{87}/Sr^{86} initial ratios of the Tanumé rocks (0.7124 ± 0.0007 (2σ) relative to the Pichilemu rocks (0.7060 ± 0.0005 (2σ), which were more affected than the former by the main (D_2) phase of deformation and metamorphism in the area.

Pre-Andean metamorphic complexes crop out along the coast ranges of Chile S of 33°S (Fig. 1). González-Bonorino (1970) and Aguirre *et al.* (1972) proposed that the western complex of more deformed rocks and the easterly metamorphic complex, which is intruded by batholithic granitoids, constituted a paired metamorphic belt. Miller (1973), on the other hand, has interpreted the two complexes as being of different ages, separated by a regional unconformity. Hervé *et al.* (1981) have suggested that the protolith of the western belt consists of accreted oceanic rocks and that of the eastern belt of a continental platform detrital series.

The contact between the two belts, designated by Ernst (1975) as the Coast Range Suture, has been interpreted as a transitional or a fault contact. The transitional nature is characterized by a progressively stronger development towards the W of a S_2 crenulation foliation, which tends to transpose and obliterate the S_1 and S_0 primary structures seen in the eastern complex.

Ruiz *et al.* (1965) considered the metamorphic rocks of the coast ranges of central Chile to be Precambrian in age. Munizaga *et al.* (1973) presented limiting whole rock reference isochrons which indicated a 342–275 Ma time bracket for a major phase of metamorphism probably associated to the development of S_2. A late Palaeozoic K-Ar age (329 ± 22 Ma) on crossite (Hervé *et al.* 1974) suggests that subduction may have been active at that time. Although some Silurian U-Pb ages (~ 400 Ma) have been obtained from higher grade metamorphic and plutonic rocks from the eastern belt near Valparaiso (Corvalán & Munizaga 1972), no Precambrian ages have been obtained in this part of S America, as they have been in Peru (Cobbing *et al.* 1977; Shackleton *et al.* 1979).

The primary objectives of this investigation were (1) to obtain whole rock Rb-Sr ages from both metamorphic complexes and (2) to use this geochronological data to test the diverse geologic relationships and supposed origin of these complexes.

Sampling and analytical procedures

Samples were collected from an outcrop less than 10 m long at Tanumé and Alcones and from 200 m of continuous shoreline outcrops at Pichilemu, in which no great structural or lithologic discontinuity is observed (Fig. 2).

Ten samples from Tanumé and Pichilemu were chosen for the isotopic determinations performed at the Centro de Pesquisas Geocronológicas of the University of São Paulo, Brazil. Rb and Sr concentrations over 40 ppm were analysed by XRF in a Philips 2KW instrument. Lower values were determined by isotope dilution with the same VARIAN Mat TH5 mass-spectrometer in which the Sr^{87}/Sr^{86} isotopic ratios were measured, following the procedures established by Kawashita (1972). The analytical precision for the Rb and Sr concentrations is *c.* 2% by XRF and 1% by isotope dilution.

Sr^{87}/Sr^{86} ratios were normalized to $Sr^{86}/Sr^{88} = 0.1194$. The average Sr^{87}/Sr^{86} ratio of the Eimer and Amend $SrCO_3$ at the laboratory is 0.7083 ± 0.0008 (1σ) (27 measurements from 13 July 1977 to 13 February 1981). A Rb^{87} decay constant of 1.42 $\times 10^{-11} yr^{-1}$ was used in all Rb-Sr calculations. The 5 Alcones samples were analysed at the Isotope Geology Unit of IGS in London, in which the XRF precision on Rb/Sr is of 0.5% and that of Sr^{87}/Sr^{86} is of 0.01% (2σ). The York (1969) method was used in the calculation of the isochrons.

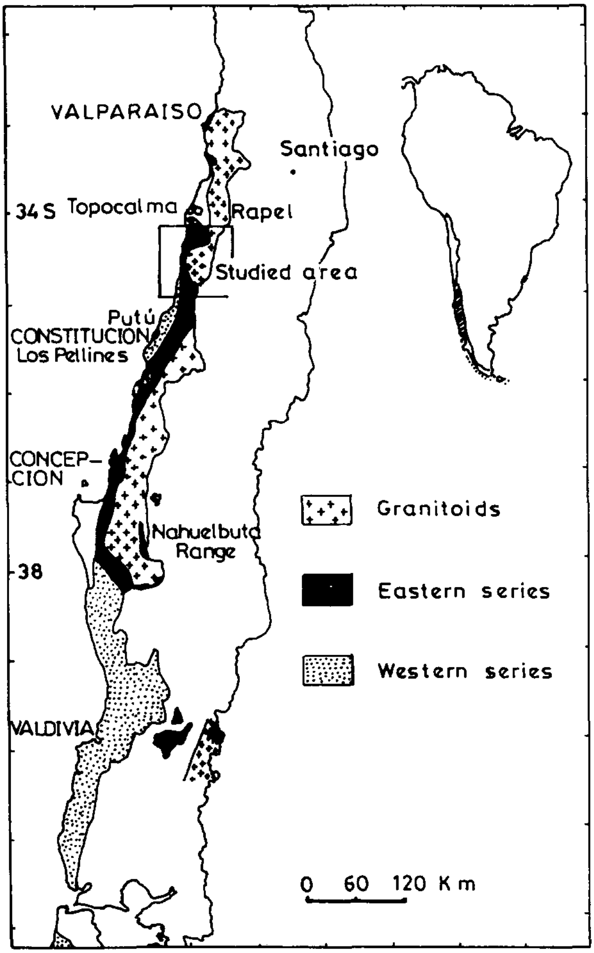

FIG. 1. Location map and distribution of pre-Andean units in the coastal range of Central Chile.

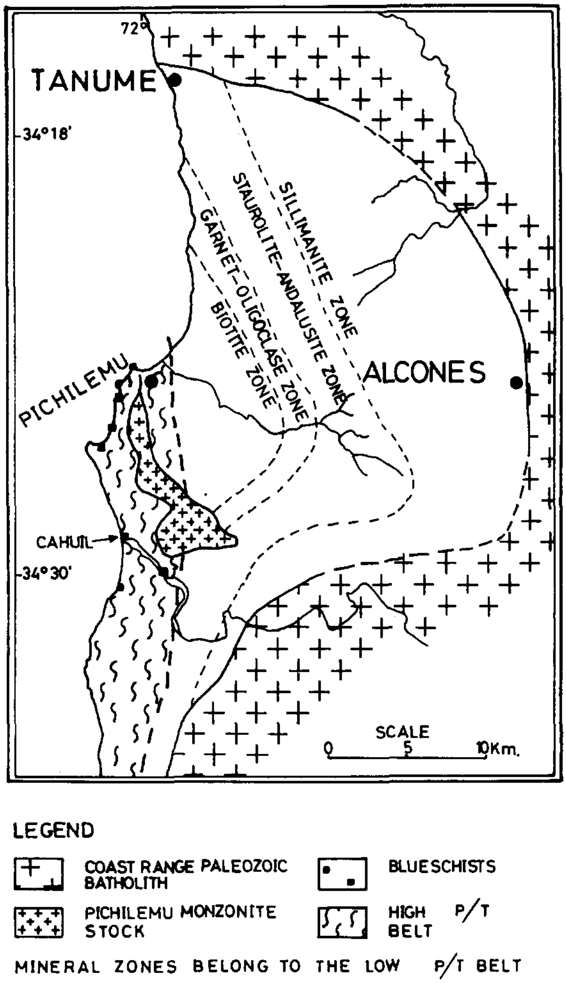

FIG. 2. Sampled localities and geology of the studied area.

K-Ar dating in São Paulo was performed after the techniques described by Amaral *et al.* (1966) and at the IGS following the routine procedures of the laboratory using an AEI MS10 mass spectrometer. Precision in the obtained ages is about 5% in each case.

The obtained Rb-Sr data are presented in Table 1. Table 2 summarizes previous geochronological data on rocks of the area. Table 3 shows new K-Ar data obtained on rocks from the studied area and related rock units relevant to the studied units.

The Tanume metamorphics

The isochron suite consists of five samples from the same outcrop at Tanumé beach. The outcrop consists of metasedimentary strata of alternating metapsammites and metapelities, with calc-silicate rocks in discontinuous lenses.

Most of the analysed samples are staurolite and/or andalusite porphyroblast-bearing quartz–muscovite–biotite schists. Their mineralogy is shown on Table 4. The staurolite porphyroblasts, up to 1 cm long, have an internal foliation discontinuous with the main (S_2) foliation, which wraps around them. Some post-tectonic chlorite is developed on the rims of the staurolite and in the groundmass. The andalusite porphyroblasts may be up to 15 cm long; they have chiastolitic habit and are partially transformed into white mica along rims and cleavages.

Table 5 shows electron probe analysis of some minerals in these rocks. In the micaschists plagioclase is close to An_{20}, the white micas are celadonite-poor sodic muscovites, Fe-Mg chlorites and Ti-rich biotites

TABLE 1: *Rb-Sr analytical data*

	*Sample no.**	Rb (ppm)	Sr (ppm)	$^{87}Sr/^{86}Sr$	$^{87}Rb/^{86}Sr$
Tanumé schists‡	PIC-1F	52.7	238.2	0.7150	0.64
	PIC-1G	191.0	136.9	0.7322	4.05
	PIC-1H	158.4	152.5	0.7264	3.01
	PIC-1B	106.8	204.3	0.7212	1.51
	PIC-1D	194.0	117.5	0.7366	4.79
Pichilemu metamorphics‡					
	PIC-4F	40.8	510.8	0.7064	0.23
	PIC-4B	153.8	14.4†	0.8467	31.3
	PIC-4K	132.5	197.7	0.7155	1.94
	PIC-4E	243.9	31.7†	0.8035	22.5
	PIC-5	19.6†	17.0†	0.7208	3.34
Alcones metamorphics§					
	PIC-2A	55.5	327.6	0.71375	0.174
	PIC-2C	175.3	61.9	0.75085	2.905
	PIC-2D	132.0	89.3	0.73432	1.516
	PIC-2F	97.0	307.2	0.71442	0.324
	PIC-2H	174.1	162.4	0.72796	1.099

* Sample numbers refer to the collection at the University of Chile, Santiago.
† Isotope dilution determinations.
‡ Analysed at CPGEO, São Paulo, Brazil.
§ Analysed at the Institute of Geological Sciences, London.

TABLE 2: *Previous isotopic dates of rocks and minerals from the metamorphic basement of Central Chile*

Locality and reference	*Material analysed*	*Rock*	*Method*	*Age* (Ma)	*Initial $^{87}Sr/^{86}Sr$ ratio*
Pichilemu (1)	whole rock	slate	K-Ar	210	
Reference isochrons (2)	whole rock	schists	Rb-Sr	342 – 275*	0.711
Cahuil (3)	crossite	qtz-crossite vein	K-Ar	329 ± 22	
Pichilemu (3)	whole rock	blue schist	K-Ar	211 ± 12	
Cahuil (3)	crossite conc.	metachert	K-Ar	211 ± 32	
Los Pellines (4)	muscovite	schist	K-Ar	270	
Concepción (5)	biotite	granitoid	K-Ar	310	
Concepción (6)	whole rocks	granitoid	Rb-Sr	312 ± 35	0.706

* 334-266 with $\lambda_{Rb}{}^{87} = 1.42 \times 10^{-11}\,y^{-1}$.
(1) González-Bonorino (1967); (2) Munizaga *et al.* (1973); (3) Hervé *et al.* (1974); (4) Dávila *et al.* (1979); (5) Nishimura (1971); (6) Hervé *et al.* (1976).

TABLE 3: *New K-Ar ages from the Tanumé–Constitución area*

Sample no.	*Locality*	*Material analysed*	*Rock*	*K* (%)	*Age* (Ma)
PIC-1G	Tanumé	whole rock	schist	3.33	299 ± 10
PIC-2F	Alcones	biotite	gneiss	7.44	278 ± 7
PIC-3	Pichilemu	biotite	granitoid	6.35	158 ± 2
PIC-5	Pichilemu	stilpnomelane	metachert	1.29	32 ± 2
0501	Constitución	biotite	granitoid	4.92	208 ± 6
271	Putu	white mica concentrate	schist	2.71	208 ± 5
IL01	Iloca	stilpnomelane	metachert	1.08	15 ± 2

TABLE 4: *Mineralogy of the analysed rocks*

Alcones gneisses	
PIC 2A	Qz, Kf, Pl, Co, Bi, Sill
PIC 2C	Qz, Kf, Co, Bi, Sill
PIC 2D	Qz, Kf, Gt, Bi, Sill
PIC 2H	Qz, Pl, Bi, Sill
PIC 2F	Qz, Pl, Bi, Sill
Tanumé metamorphics	
PIC 1B	Qz, Ms, Bi, St, And
PIC 1H	Qz, Ms, Bi, St
PIC 1D	Qz, Ms, Bi, St
PIC 1F	Qz, Pl, Gt, Di, Ep, Bi
PIC 1G	Pl, Bi, Wm, Chl, And, Il
Pichilemu metamorphics	
PIC 4B	Qz, Wm, Chl
PIC 4E	Qz, Wm, Chl
PIC 4F	Naa, Chl, Wm, Cc, Op
PIC 4K	Naa, Chl, Wm, Ep, Cc, Ab, Op
PIC 5	Qz, Ab, F stilp, Ac

Qz = quartz; Kf = orthoclase; Pl = plagioclase; Co = cordierite; Bi = biotite; Sill = sillimanite; Gt = garnet; St = staurolite; And = andalousite; Ms = muscovite; Di = diopside; Ep = epidote; Wm = white mica; Chl=chlorite; Il = ilmenite; Naa = Na – amphibole; Cc = calcite; Op = opaque minerals; Ab = albite; F stilp = Ferrostilpnomelane; Ac = Actinolite.

are also present. Pyrite and ilmenite are opaque mineral phases and Ba-rich K-feldspar veins are present in the calc silicate rocks.

The mineral assemblages are indicative of the amphibolite facies. According to González-Bonorino (1970) they belong to a metamorphic sequence with chlorite and biotite zones in the lower grades, and sillimanite-bearing zones in the higher grades. They may thus be included in a typical low to intermediate pressure metamorphic facies series (Aguirre *et al.* 1972) which is supported by the chemistry of the white micas, high in Na and low in celadonite component.

The isotopic data presented in the Rb-Sr isochron diagram of Fig. 3 define a 347 ± 32 (2σ) Ma whole rock isochron, with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7124 ± 0.0007 (2σ).

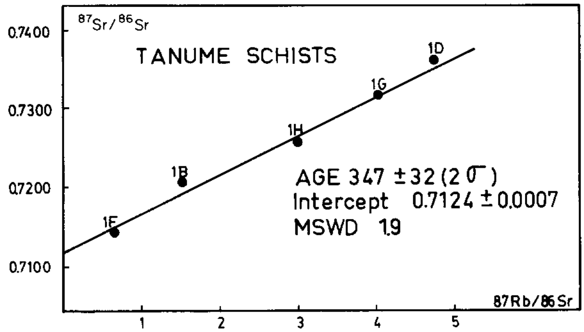

FIG. 3. Rb-Sr isochron plot of the Tanumé metamorphics.

Sample PIC 1G, included in the isochron, gave a 299 Ma K-Ar age for a concentrate of finer grained mica-rich matrix (Table 3).

The Alcones gneisses

The analysed samples come from a small outcrop on the creek bed, near Alcones water reservoir (Fig. 2). The rocks consist mainly of coarse-grained sillimanite-bearing banded gneisses with some granitic garnet-bearing bands. Their mineralogy is shown on Table 4.

Some phyllonitic bands of finer-grained, well-oriented biotite crystals, rounded undulose quartz and plagioclase crystals reveal late deformation events. Partial chloritization of biotite and transformation of cordierite to pinnite and white mica is observed.

The mineral assemblages are indicative of high amphibolite or low granulite facies (González-Bonorino 1970). The T of the upper stability limit of muscovite appears to have been exceeded. These rocks belong to the high grade zone of the same low to intermediate P metamorphic series (Aguirre *et al.* 1972) to which the previously described Tanumé metamorphics belong.

The isotopic data presented in the Rb-Sr isochron diagram of Fig. 4 defines a crude 'errorchron' of 370 Ma (MSWD = 190) with an initial $^{87}Sr/^{86}Sr$ ratio

TABLE 5: *Representative mineral compositions from Tanumé metamorphics*

	Plagioclase (PIC 1G)	*White mica* (PIC 1B)	*Biotite* (PIC 1G)	*Chlorite* (PIC 1G)	*Epidote* (PIC 1F)
SiO_2	64.69	45.59	34.13	25.19	38.24
TiO_2	—	0.47	1.41	—	—
Al_2O_3	24.62	37.25	20.71	25.71	30.85
FeO"	—	0.74	24.38	31.47	4.76
MnO	—	—	—	0.36	—
MgO	—	0.59	7.36	11.30	—
CaO	4.01	0.15	—	0.04	23.56
Na_2O	9.38	1.55	—	—	—
K_2O	0.10	9.02	7.99	—	—
	102.81	95.36	95.98	94.07	97.42

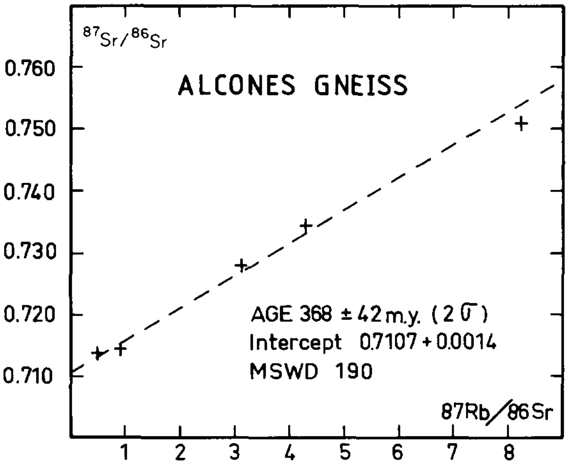

FIG. 4. Rb-Sr plot of the Alcones gneisses.

of 0.7107. Multiplying error estimates of the age and the initial ratios by $\sqrt{(MSWD)}$ gives an uncertainty of ±42 Ma on the age and of ±0.0014 on the initial $^{87}Sr/^{86}Sr$ ratio. A biotite concentrate of PIC 2F, sample included in the errorchron, gave a K-Ar age of 278 ± 7 Ma (Table 3).

The Pichilemu metamorphics

In this area, greenschists predominate and some residual volcanic breccia textures are observed. Metamorphosed pillow basalts belonging to the same unit crop out 3 km S of the sampled area. They have similar mineralogy to the greenschists analysed here. Metacherts occur as discontinuous boundinaged bands and rootless intrafolial folds dispersed in a sheared metabasite or metapelite matrix, in a mélange-type structure. Some small post-tectonic mafic dykes are observed.

The analysed Pichilemu metamorphics are blue amphibole-bearing metabasites (PIC 4F and 4K), fine-grained quartzose phyllites (4B & 4E) and a stilpnomelane-rich metachert (PIC-5). Their mineralogy is shown on Table 4.

Chemical composition of some mineral phases appear in Table 6. The feldspar is almost pure albite in all the samples. The white mica present in metacherts and metabasites is celadonite-rich muscovite. Chlorite varies from Fe-Mg to Mg-Fe varieties depending on the rock type. Epidote is Fe-rich pistacite, and ilmenite and titanomagnetite are the opaque minerals. Actinolite occurs in the metacherts together with abundant stilpnomelane, while crossite and magnesio riebeckite are present in the metabasites.

The mineral assemblages and compositions correspond to glaucophanitic greenschist facies and are included in the intermediate to high P/T series of Aguirre *et al.* (1972).

The Rb-Sr isochron diagram (Fig. 5) shows a well-defined 311 ± 10 (2σ) Ma whole rock isochron with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7060 ± 0.0005 (2σ).

Hervé *et al.* (1974) obtained K-Ar ages of 329 ± 22 Ma from coarse crossite veins, and 211 Ma from crossite concentrate and whole-rock schist from a nearby area of the same rock unit (Table 2). González-Bonorino (1967) presented a 210 Ma K-Ar age on metapelite from the same outcrops analysed here. Biotite from the Pichilemu pluton (Fig. 1; Table 3) yielded a 158 Ma K-Ar age, which must be considered a minimum cooling age. Stilpnomelane K-Ar ages (Table 3) of 32 ± 2 and 15 ± 2 Ma cannot be related to any known geological event in the area and probably reveal continuous Ar loss at low temperatures in these minerals.

Discussion and interpretation of data

The interpretation of isotopic ages in metamorphic rocks is often difficult, but is facilitated by a thorough

TABLE 6: *Representative mineral analyses from Pichilemu metamorphics*

	Albite	*White Mica*		*Chlorite*		*Epidote*
	(PIC 4J)*	(PIC 4J)*	(PIC 4F)†	(PIC 4J)	(PIC 4F)†	PM5198†
SiO_2	69.07	48.35	49.64	29.08	33.40	38.30
TiO_2	—	0.42	0.08	0.03	—	—
Al_2O_3	19.12	24.06	22.17	20.63	22.36	25.00
FeO″	0.30	6.47	5.56	25.00	14.91	11.24
MnO	—	—	—	0.40	0.19	—
MgO	—	5.51	6.50	17.7	30.99	—
CaO	0.01	0.09	0.18	0.61	0.25	23.68
Na_2O	11.59	—	0.70	—	0.09	—
K_2O	0.18	10.17	10.60	—	0.73	0.01
	100.26	95.08	95.43	93.11	102.94	99.00

* Metachert.
† Metabasite.

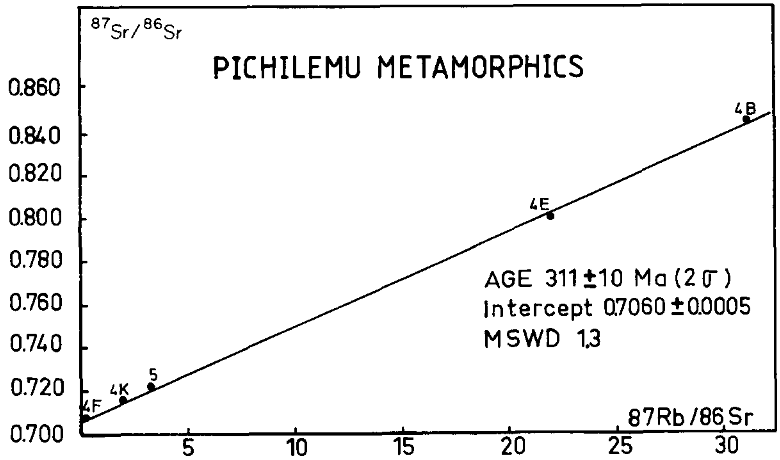

FIG. 5. Rb-Sr isochron plot of the Pichilemu metamorphics.

understanding of the deformational and metamorphic history of the analysed rocks.

The results presented here, besides being the first isochrons for the metamorphic basement in Central Chile, allow an evaluation of some aspects of the geologic evolution of both metamorphic complexes.

The Tanumé metamorphics, whose protolith was deposited in a fore-arc basin, have an initial ratio (0.712) which indicates recycled crustal material, as would be expected from a continental clastic sequence. Similar high values (0.711) for the Alcones gneiss probably indicate that both areas share some common history. The source areas are unknowns, but probably relate to the early Palaeozoic to Late Precambrian terrains which outcrop 250 km E of the area, in Argentina (Caminos *et al.* 1982).

On the other hand, the rather low initial ratio (0.706) of the Pichilemu metamorphics correlates well with the supposed oceanic nature of its protolith, and supports the idea that they contain an accreted oceanic component.

The structural characteristics of both complexes indicate a polyphase deformational history (González-Bonorino 1970; Hervé 1977; Gana 1981) which is not understood in detail. Correlation of deformation events between the two complexes is made on the assumption that S_2 foliation in both of them is contemporaneous.

In the Tanumé metamorphics, well-preserved stratification (S_0) and a first foliation (S_1) are clearly recognized in the microlithons generated by S_2.

On the contrary, on the accreted belt, i.e. Pichilemu schists, S_2 is very penetrative, S_0 being very seldom preserved and S_1 is mainly detected as folded inclusion trails in pre-S_2 albite porphyroblasts.

This situation may explain the older and poorly defined 347 ± 32 (2σ) Ma age isochron at Tanumé and the 368 Ma errorchron at Alcones, as compared with the younger and better-defined (310 ± 10 (2σ) Ma) isochron at Pichilemu. The less penetrative character of S_2 at Tanumé and Alcones might have caused 'partial' or 'incomplete' Sr isotope requilibration, whilst the penetrative characteristics of S_2 at Pichilemu might have produced the complete homogenization of Sr isotopes on rocks of very differing Rb and Sr concentration. The late partial alteration of the staurolite and andalusite porphyroblasts at Tanumé and of cordierite at Alcones is also a possible cause of isotopic disturbance in the studied rocks. On the contrary, lack of zoning in feldspars and garnets in the Pichilemu rocks, as well as absence of alteration minerals might indicate that equilibrium was attained in these rocks which was not affected by post metamorphic processes.

The 299 Ma K-Ar age for the Tanumé metamorphics and the 278 Ma age at Alcones (Table 3) indicate that shortly after the development of S_2, the units were uplifted and cooled below the critical retention temperature of the micas. If we consider that the Tanumé and Alcones metamorphics contain rather high T minerals, the uplift must have been quite considerable. The 329 ± 22 Ma K-Ar age of crossite at Cahuil (see Fig. 2) in the Pichilemu metamorphics points to the same rapid uplift, and may also indicate that it proceeded earlier in the westernmost parts of the metamorphic complex.

After penetrative deformation ceased in the area, probably due to the westward migration of the subduction zone, the Constitución and Pichilemu monzonite stocks intruded the Pichilemu complex (see Fig. 1). The epizonal Constitución stock has intrusive contacts with the surrounding rocks (Godoy 1970; Gana 1981) and a 208 Ma K-Ar biotite age, which may be close to the emplacement age. The Pichilemu

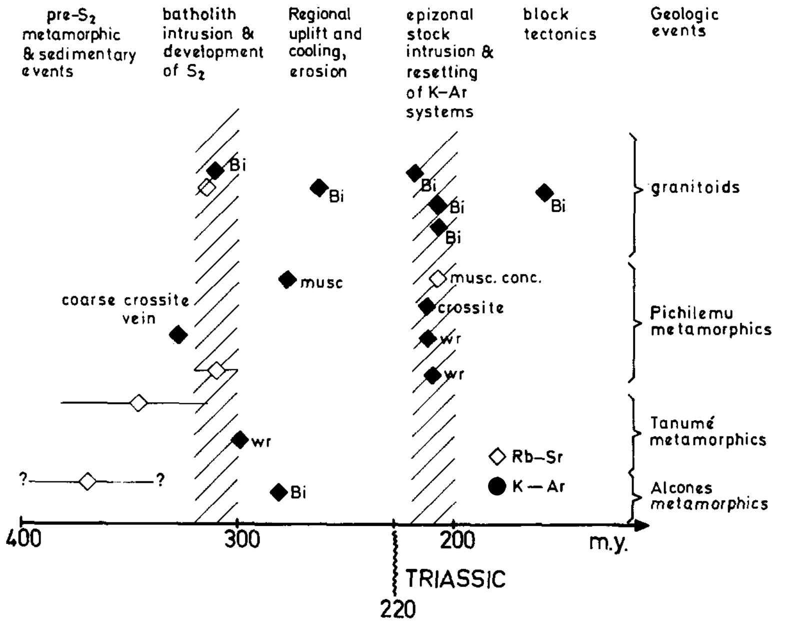

FIG. 6. Summary of isotopic ages and geological history of the area (m.y. = million years)

stock gave a 158 Ma K-Ar biotite age, which may represent a cooling age after upward tectonic transport. The 208 to 211 Ma ages in rocks and minerals of the area (Table 2) might indicate that during that period the intrusion of the stocks heated the area and reset the K-Ar ages at least for the fine-grained whole-rock K-Ar systems.

Figure 6 presents a summary of isotopic ages and the geological history inferred from them for this area.

ACKNOWLEDGEMENTS. Field work was financed by Grant E083 of the University of Chile. Age determinations at São Paulo were possible due to the IGCP Project 120 'Magmatic Evolution of the Andes'. Isotope analysis at IGS, London was possible due to a J. S. Guggenheim Fellowship and support given by the Royal Society of London to F. Hervé. Drs R. Pankhurst and N. Snelling provided invaluable support on the analytical work and kindly revised early versions of the manuscript.

References

AGUIRRE, L., HERVÉ, F. & GODOY, E. 1972. Distribution of metamorphic facies in Chile: an outline. *Krystallinikum,* **9,** 7–19.

AMARAL, G., CORDANI, U. & KAWASHITA, K. 1966. K-Ar dates of basaltic rocks from southern Brasil. *Geochim. cosmochim. Acta,* **30,** 159–89.

CAMINOS, R., CINGOLANI, C. HERVÉ, F. & LINARES, E. 1982. Geochronology of the pre-Andean metamorphism and magmatism in the Andean Cordillera between latitudes 30° to 36°S. *Earth Sci. Rev.* **18,** 333–52.

COBBING, E. J., OZARD, J. M. SNELLING, N. J. 1977. Reconnaissance geochronology of the crystalline basement rocks of the Coastal Cordillera of Southern Peru. *Bull. geol. Soc. Am.* **88,** 241–6.

CORVALÁN, J. & MUNIZAGA, F. 1972. Edades radiométricas de rocas metamórficas e intrusivas de la Hoja Valparaiso–San Antonio. *Bull. Inst. Invest. Geol. Santiago,* **28,** 1–40.

DÁVILA, A., MUNIZAGA, F. & HERVÉ, F. 1979. Edades K-Ar en granitoides de la Cordillera de la Costa de la Provincia de Colchagua, VI Regiōn, Chile Central. *Acta II Congr. Geol. Chileno,* **T-1,** F107–F120.

ERNST, W. G. 1975. Systematics of large-scale tectonics and age progressions in Alpine and Circum-Pacific blueschists belts. *Tectonophysics,* **26,** 229–246.

GANA, P. 1981. *Geología de la Cordillera de la Costa entre los rios Mataquito y Maule.* Unpubl. thesis, Univ. Chile.

GODOY, E. 1970. *El granito de Constitución y su aureola de metamorfismo de contacto.* Unpubl. thesis, Univ. Chile.

GONZÁLEZ-BONORINO, F. 1967. Nuevos datos de edad absoluta del basamento cristalino de la Cordillera de la costa de Chile central. *Depto de Geología, Univ. de Chile, Santiago, Serie Notas y Comunicaciones,* **1,** 8 p.

—— 1970. Series metamórficas del basamento cristalino de la Cordillera de la Costa, Chile Central. *Publication* No **37,** *Dept Geol., Univ. Chile,* 68 pp.

HERVÉ, F. 1977. Petrology of the crystalline basement of the Nahuelbuta Mountains, south central Chile. *In*: ISHIKAWA, T. & AGUIRRE, L. (eds) *Comparative Studies of the Circumpacific Orogeny in Chile and Japan,* Tokyo.

——, Davidson, J., Godoy, E., Mpodozis, C. & Covacevic, V. 1981. The Late Palaeozoic in Chile: stratigraphy, structure and possible tectonic framework. *An. Acad. bras. Cienc.* **53,** 361–73.

Hervé, F., Munizaga, F., Godoy, E. & Aguirre, L. 1974. Late Palaeozoic K/Ar ages of blueschists from Pichilemu, Central Chile. *Earth planet. Sci. Lett.* **23,** 261–264.

——, ——, Mantovani, M. & Hervé, M. 1976. Edades Rb-Sr neopaleozoicas del basamento cristalino de la cordillera de Nahuelbuta. *Actas 1 Congr. Geol. Chile,* F19–F26.

Kawashita, K. 1972. *O Metodo Rb-Sr en rochas sedimentares. Applicacao para as bacias de Paraná e Amazonas.* Unpubl. PhD thesis, Univ. São Paulo.

Miller, H. 1973. Características estructurales del basamento geológico chileno. *Actas V Congr. Geol. Argentino,* **4,** 101–15.

Munizaga, F., Aguirre, L. & Hervé, F. 1973. Rb/Sr ages from the Chilean metamorphic basement. *Earth planet. Sci. Lett.* **18,** 87–92.

Nishimura, T. 1971. Acerca de la estratigrafía de Magallanes (in Japanese). *Biol. Serv. geol. Hokkaid,* **44,** 45 p.

Ruiz, C. 1965. *Geología y Yacimientos Minerales de Chile.* Ed. Instituto de Investigaciones Geológicas, Santiago, 386 p.

Shackleton, R. M., Ries, A. C. & Coward, M. P. 1979. Structure, metamorphism and geochronology of the Arequipa Massif of Coastal Peru. *J. geol. Soc. London,* **136,** pp. 195–214.

York, D. 1969. Least squares fitting of a straight line with correlated errors. *Earth planet. Sci. Lett.* **5,** 320–4.

Received 16 September 1983; revised typescript accepted 20 February 1984.

F. Hervé & F. Munizaga, Departamento de Geología, Universidad de Chile, Casilla 13518, Correo 21 Santiago, Chile.

K. Kawashita & M. Bassei, Centro de Pesquisas Geocronológicas, Universidade de São Paulo, C.P. 20899, São Paulo, Brazil.