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ESTUDIOS ISOTOPICOS U-Pb Y Rb-Sr DE ROCAS SEDIMENTARIAS DE LA QUEBRADA LAS ANIMAS (26°25'S) CORDILLERA DE LA COSTA CHILE

U-Pb AND Rb-Sr ISOTOPIC SYSTEMATICS OF METASEDIMENTARY ROCKS FROM QUEBRADA LAS ANIMAS (26°25'S), COASTAL RANGE, CHILE

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The oldest rocks exposed in the North Chilean Coast Range are Paleozoic metasedimentary rocks which were placed into the Devonian by Zeil (1964) or into the Middle Devonian by Miller (1970). Recent studies (Bell 1982) comprise Ordovician to Devonian strata. The generally monotonous series of thick psammitic and thinner pelitic layers, sporadically with trace fossil prints, are considered to be affected by low-grade metamorphism probably during a Variscan event (Miller, 1970).

The area of the present study (26°25' S, 70°30' W, fig.1) is located in the Quebrada Las Animas, ten kilometers southeast of the town of Chañaral. 1.100.000 scaled geological maps by Mercado (1978, 1980) and Naranjo (1978) show tonalitic and granitic tocks of probable Paleozoic age intruded into the Devonian metasedimentary rocks along the coast. Damm & Pichowiak (1981) generate granitic rocks from the Chañaral-Taltal area by anatexis of lower continental crust with S-type characteristics while towards the interior of the continent Mesozoic I-type intrusions with more basic characteristics and intercalations of volcanic sequences predominate (Berg & Breitkreuz 1983).

The metasedimentary rocks in the area of the Quebrada Las Animas consist of a 5000 m thick sequence of arkosic quartzites and minor metasiltones (inset in fig.1). Some samples of this suite have been investigated by the U-Pb and Rb-Sr methods to obtain information on the problem of the possible relationship to the plutonites (Berg & Baumann, 1985). The question arises whether these metasedimentary rocks could have contributed to the genesis of the granitoid rocks with higher initial $^{87}Sr/^{86}Sr$ ratios in the area northeast of Chañaral. U-Pb data of zircons from one arcosic quartzite sample - the first ones from this rock type in the Coast Ranges of Northern Chile-are presented.

Isotope analyses were carried out at the Institut für Mineralogie, Münster following standard procedures there. Isotopic ratios were measured on a Teledyne NBS-type 12"90 solid source mass spectrometer. Estimated uncertainties are ± 0.8% for $^{207}Pb/^{235}U$, ± 0.6% for $^{206}Pb/^{238}U$ and ± 0.4% for $^{207}Pb/^{206}Pb$. The average of values for the NBS SRM 987 Sr standard measured during this study was 0.71038 ± 0.00004. Element

concentration and ages were calculated using the constants recommended by the IUGS Subcommission on Geochronology, Steiger & Jäger (1977). Errors quoted in this paper are 2 standard deviations of the mean.

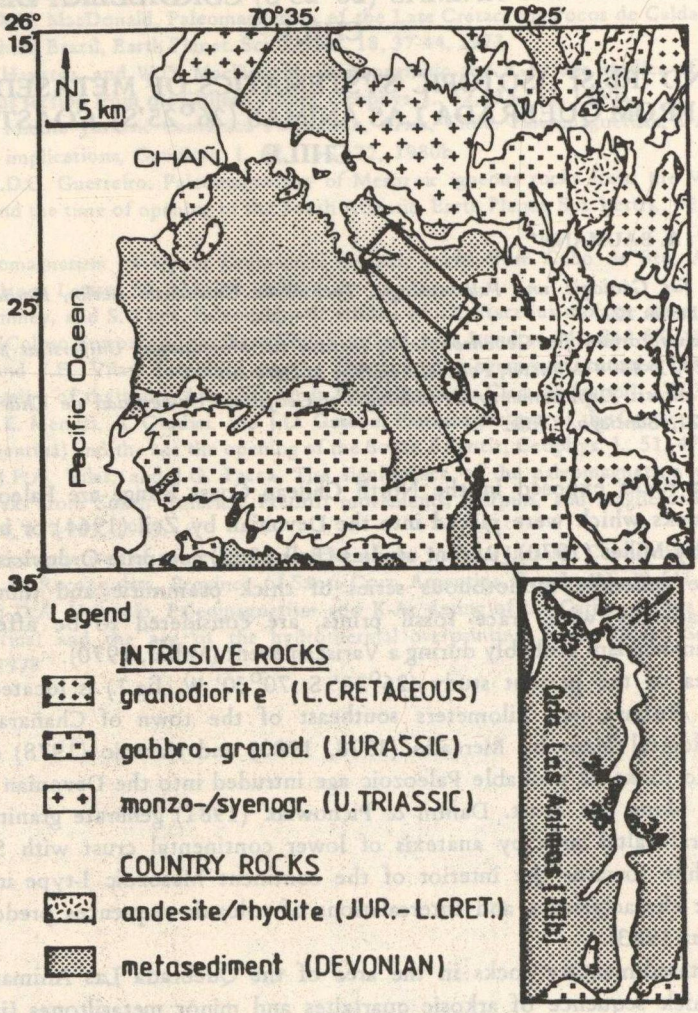

Fig. 1. Generalized geological map of the Chañaral area with the paleozoic metasedimentary rock sample district (Quebrada Las Animas) and the mesozoic magmatites.

Fig. 1. Mapa Geológico Generalizado del área de Chañaral indicando las metasedimentitas muestreadas (Quebrada Las Animas y las magmáticas mesozoicas.

U-Pb Isotopic Systematics

Sized zircon fractions of sample IIIb-33 show a great variety of euhedral to sub-rounded shapes and of colorless and pink to light and dark brown colors. The U-Pb data of the zircon fractions display two distinct linear arrays in the concordia diagram (fig.2): one for the colorless zircons and another one for the pink to dark brown crystals including a "magnetic" fraction and a fraction < 25 μm. Though the data points plot along two separate regression lines, giving the impression of two

TABLA 1

DATOS U-Pb DE LOS CIRCONES DE CUARCITA ARCOSICAS (IIIb-33) DE QUEBRADA LAS ANIMAS (26°23'58" Y 70°31'23")

U-Pb DATA OF ZIRCONS FROM THE ARCOSIC QUARTZITE SAMPLE (IIIb - 33) OF QUEBRADA LAS ANIMAS (26°23'58" AND 70°31'23")

N°in fig.2	Sieve fraction (μm)	Remarks	Analyzed (mg)	Concentrations $U_{tot.}$ (ppm)	$Pb_{tot.}$ (ppm)	$^{206}Pb_{rad}$ (nmol/g)	Observed atomic ratios $\frac{^{208}Pb}{^{206}Pb}$	$\frac{^{207}Pb}{^{206}Pb}$	$\frac{^{206}Pb}{^{204}Pb}$	Atomic ratios corrected for common Pb and blank $\frac{^{206}Pb}{^{238}U}$	$\frac{^{207}Pb}{^{235}U}$	$\frac{^{207}Pb}{^{206}Pb}$	Apparent ages (Ma) $\frac{^{206}Pb}{^{238}U}$	$\frac{^{207}Pb}{^{235}U}$	$\frac{^{207}Pb}{^{206}Pb}$
1	50 - 250	a,c,f	3.0	369.7	46.76	1774	0.16635	0.10015	874	0.11505	1.33322	0.08405	702.0	860.3	1294
2	<25	a,c,d	5.0	631.5	75.40	3064	0.10195	0.08985	3327	0.11631	1.37318	0.08563	709.3	877.2	1330
3	63 - 100	a,c	2.6	382.7	47.46	1906	0.12233	0.08841	2711	0.11934	1.36989	0.08322	727.0	876.1	1274
4	100 - 200	b,d	1.5	636.6	86.73	3480	0.10501	0.10618	2409	0.13105	1.81528	0.10047	793.8	1051	1633
5	125 - 160	a,c	2.6	258.9	34.33	1356	0.13642	0.09471	2117	0.12560	1.52576	0.08810	762.7	940.8	1385
6	125 - 160	b,c	4.4	145.4	20.87	807	0.18227	0.10044	3263	0.13153	1.74465	0.09620	796.6	1025	1552
7	125 - 160	b,d	5.3	511.4	57.62	2375	0.09836	0.08149	12183	0.11132	1.23298	0.08033	680.4	815.7	1205
8	125 - 160	a,c,d,b,e	12.0	439.2	59.98	2379	0.12164	0.09698	4091	0.12986	1.67555	0.09358	787.0	999.3	1500
9	125 - 200	b,e	3.2	963.9	122.35	5104	0.06497	0.09683	7126	0.12696	1.66099	0.09488	770.5	993.8	1526
10	160 - 250	b,d,e	3.4	312.1	37.26	1477	0.13605	0.08794	2193	0.11345	1.27493	0.08151	692.7	834.6	1234

a euhedral
b subrounded
c clear
d pink to light brown
e dark brown
f magnetic at 1.4A, 2°side slope

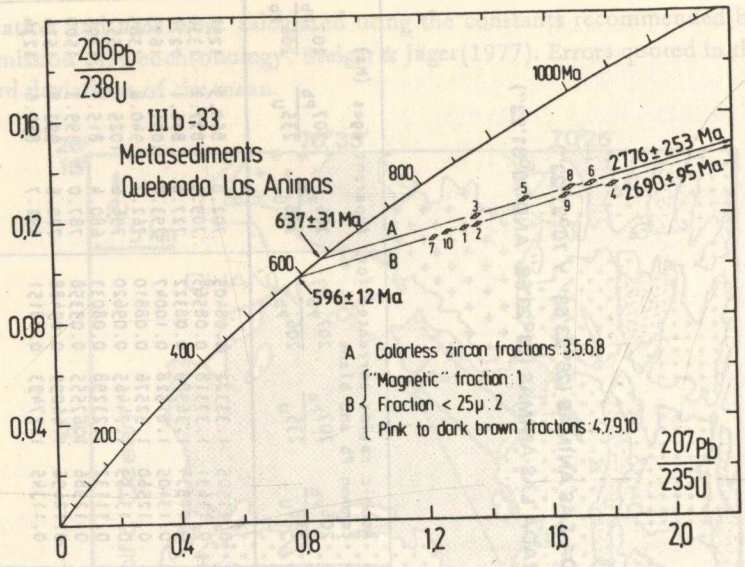

Fig. 2. U-Pb concordia diagram of zircons from the arkosic quart zite sample of Quebrada Las Animas.
Fig. 2. Diagrama Concordia U-Pb de circones de la cuarcita arcósica de Quebrada Las Animas.

different zircon populations, the errors of the upper and lower intercepts of the lines with the concordia are overlapping. In general the colorless zircon fractions have lower U and Pb concentrations than the pink to dark brown ones (Tab.1). This is particularly evident from the clear fraction n° 6 (125-160 µm) with 145 ppm U and 21 ppm Pb and the dark brown fraction n° 9 (125-200 µm) with 964 ppm U and 122 ppm Pb.

Rb-Sr Isotopic Systematics

Five whole-rock samples of arkosic quartzites and a pelitic sample, grading into phyllite, from two localities in the Quebrada Las Animas (fig.1 and 3) were analysed. A regression line through the data points of all six samples with a slope corresponding to an age of 220 ± 24 Ma (intercept at 0.7169 ± 0.0015) does not define an isochron in a strict sense (MSWD ≐ 3.5) indicating incomplete isotopic homogenization. The data points of the three samples from the eastern locality (fig.3, nos. 24, 25,34) and the U-Pb sample (n° 33) from the western locality, about 4 km. apart, perfectly fit a regression line in the isochron diagram with a slope corresponding to 235 Ma and an intercept at 0.7173. The data points of the two other samples from the western locality (nos. 1 and 6) are offset from this line. The slope of the line through these two points corresponds to 245 Ma and an intercept at 0.7143.

Since the data suggest incomplete isotopic homogenization, as mentioned above, over the great distance of about 4 km in a terrain of contact metamorphism these lines are not considered to be isochrones and are rather used as reference lines. It is however striking that the dates corresponding to the slopes of the lines coincide with the intrusion ages of S-type granitoid rocks of the Chañaral area (Berg & Baumann, in press).

Thus it is very likely that the Rb-Sr data document an event within a time span

between 245 and 235 Ma which reset the Rb-Sr isotopic system. This event which produced S-type granitoid rocks probably transformed the sediments by contact metamorphism.

An estimate of the maximum stratigraphic age of the Quebrada Las Animas metasediments may be tentatively obtained by assuming an average value of the $^{87}Sr/^{86}Sr$ ratio of 0.706 ± 0.001 at the time of deposition. This value is believed to represent the lowest possible Sr composition of the original sediments. Taking the average $^{87}Rb/^{86}Sr$ ratio of 4.9 ± 1,9 and the average $^{87}Sr/^{86}Sr$ ratio from the intercepts of the reference lines of figure 3 into account a maximum deposition age may be calculated on the basis of the $^{87}Sr/^{86}Sr$ evolution:

$$t_o = \frac{1}{\lambda} \cdot \frac{0.7158\ (\pm 0.0015) - 0.706\ (\pm 0.001)}{4.9\ (\pm 1.9)} + 240\ Ma$$

yields 380 ± 59 Ma.

Though this procedure leads to a rather speculative result, this is in agreement with the stratigraphic classification by field investigations (Zeil 1964, Miller 1970).

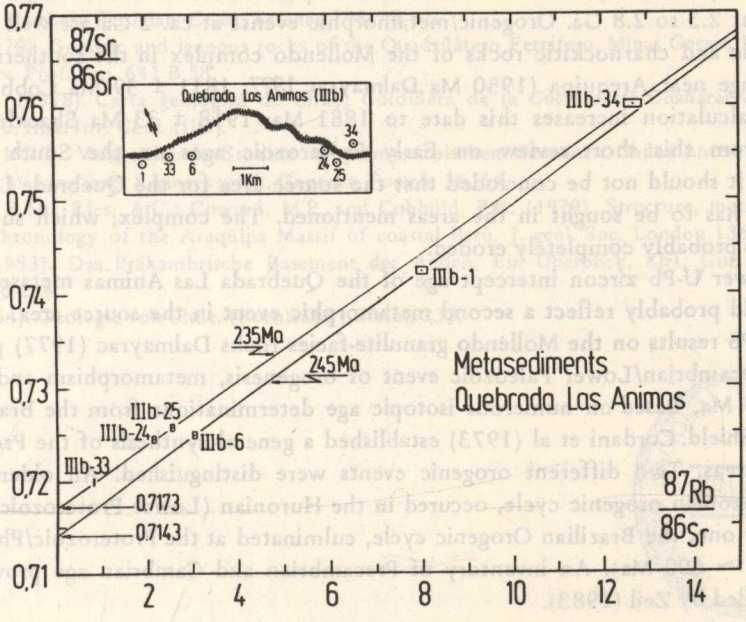

Fig.3. $^{87}Rb/^{86}Sr$ vs. $^{87}Sr/^{86}Sr$ diagram of arkosic quartzites from the metasedimentary rock suite of Quebrada Las Animas.

Fig. 3. Diagrama isocrónico para las cuarcitas arcósicas de la secuencia metasedimentaria de Quebrada Las Animas.

Discussion

The U-Pb data of the zircons and the Rb-Sr data reveal a complex geological history of the metasedimentary rocks of the Chañaral area. The strong discordance of the U-Pb data points indicates a considerable contribution of a 2.5 Ga old component to the composition of the zircons. An event at about 600 Ma caused new zircon growth

probably around older cores. The pattern of such zircon data arrays in the concordia diagram may be caused by several mechanisms:

1. The detrital zircons may be derived from at least two different Proterozoic source area (s) or a source area of different petrographic composition.
2. The uplift prior to the denudation of the source area and deposition of the sediments in the Devonian or
3. The contac-metamorphic overprinting at 235 - 245 Ma or
4. Slight recent lead loss of the zircons

may have affected the colored high-U zircons more than the clear low-U species. For the cases (2) - (4) the lower intercept age of the zircons has to be taken for a minimum age.

The old zircon component obviously indicates the age of an igneous or metamorphic event in the Proterozoic source area (s) of the metasedimentary rocks. Since the U-Pb data of the zircons plot in the lower sections of the discordia lines the upper intercepts are not well defined, i.e. the exact age of the source area remains unknown.

Ages of $>$ 2.5 Ga were reported by Herz (1970) from the Quadrilatero Ferrifero of Minas Gerais in Brazil. The oldest metamorphic rocks in this area yielded dates from about 2.3 to 2.8 Ga. Orogenic/metamorphic events at ca. 2 Ga are well established for granitic and charnockitic rocks of the Mollendo complex in the southern Peruvian Coast Range near Arequipa (1950 Ma Dalmayrac 1977; 1811 ± 39 Ma Cobbing et al. 1977, recalculation increases this date to 1881 Ma; 1918 ± 33 Ma Shackleton et al. 1979). From this short review on Early Proterozoic ages on the South American continent it should not be concluded that the source area for the Quebrada Las Animas sediments has to be sought in the areas mentioned. The complex, which supplied the detritus, is probably completely eroded.

The lower U-Pb zircon intercept age of the Quebrada Las Animas metasedimentary rocks could probably reflect a second metamorphic event in the source area. According to the U-Pb results on the Mollendo granulite-facies rocks Dalmayrac (1977) postulated a Late Precambrian/Lower Paleozoic event of orogenesis, metamorphism and uplift at about 600 Ma. Based on numerous isotopic age determinations from the Brazilian and Guayana Shield, Cordani et al (1973) established a general synthesis of the Precambrian in these areas. Two different orogenic events were distinguished. An older one, the Trans-Amazonian orogenic cycle, occured in the Huronian (Lower Proterozoic, $\geq$ 2 Ga). A younger one, the Brazilian Orogenic cycle, culminated at the Proterozoic/Phanerozoic boundary ($\sim$ 600 Ma). An inventory of Precambrian and Cambrian age provinces was also compiled by Zeil (1983).

Conclusions

As long as no more data on other metasedimentary rocks from northern Chile are available the following evolutionary model for the Quebrada Las Animas metasedimentary rocks is tentatively proposed:

1. The detrital zircons from the metasedimentary rocks of nothern Chilean Coast Range were derived from a 2.5 Ga old area- probably part of the Brazilian Shield.
2. This source area underwent metamorphism at the Proterozoic/Cambrian boundary.
3. Due to uplift in the Lower Paleozoic this area supplied the material for the sediment deposited in the Devonian. (Zeil 1964, Miller 1970). A maximum deposition, age, calculated on the basis of the $^{87}Sr/^{86}Sr$ evolution, yields 380 ± 59 Ma. Flute marks

in the metasedimentary rocks indicate one dominant direction of transport towards SSE, Bell (1982).

4. During the Permian and Triassic the area of the deposited sediments was uplifted and the S-type plutonites intruding into shallow depths transformed the sediments into metasedimentary rocks by contact metamorphism. The $^{87}Sr/^{86}Sr$ ratios at the time of contact metamorphism, deduced from the intercepts of the reference lines, range between 0.7173 and 0.7143.

REFERENCES

Bell, C.M. (1982). The lower Paleozoic metasedimentary basement of the coastal ranges of Chile between 25°30' and 27°S, Rev. Geol. Chile 17, 21-29.

Berg, K.; Baumann, A. (1985). Plutonic and Metasedimentary Rocks from the Coastal Range of Nothern Chile: Rb-Sr and U-Pb Isotopic Systematics, Earth Planet Sci. Lett., 75, 101-115.

Berg. K. and Breitkreuz, C. (1982). Mesozoische Plutone in der nordchilenischen Küstenkordillere: Petrogenese, Geochronologie und Geodynamik mantelbetonter Magmatite, Geotekt, Forsch. 66 pp. 107.

Cobbing, E.J.; Ozard, J.M. and Snelling, N.J. (1977). Reconaissance geochronology of the crystalline basement rocks of the Coastal Cordillera of Southern Perú, Büll. Geol. Soc. Amer. 88, 241-246.

Cordani, U.G.; Amaral, G. & Kawashita, K. (1973). The Precambrian evolution of South America, Geol. Rdsch. 62, 309-317.

Dalmayrac, A. (1977). Two billion-year granulites in the Late Precambrian metamorphic basement along the southern Peruvian Coast, Science 198, 49-51.

Herz, N. (1970). Gneissic and igneous rocks of the Quadrilátero Ferrífero, Minas Gerais, Brasil, U.S. Geol. Surv. Prof. Pap. 641 B 58.

Mercado, M. (1978). Carta geológica de Chile, Cordillera de la Costa entre Chañaral y Caldera, 1:100.000, Inst. Inv. Geol. (IIG).

Miller, H. (1970). Vergleichende Studien an prämesozoischen Gesteinen Chiles unter besonderer Berücksichtigung ihrer Kleintektonik, Geotekt. Forsch. 36, 64.

Shackleton, R.M.; Ries, A.C.; Coward, M.P. and Cobbold, P.R. (1979). Structure, metamorphism and geochronology of the Arequipa Massif of coastal Perú, J. geol. Soc. London 136, 195-214.

Zeil, W., (1983). Das Präkambrische Basement der Anden. Ein Uberblick, Zbl, Gol. Paläont I, (3/4), 246-254.

Zeil, W. (1964). Geologie von Chile. (Bornträger) Berlin, 233.