

## Scapolite veins in a quartz monzodiorite stock from Los Molles, Mendoza, Argentina

EDUARDO J. LLAMBIAS<sup>1</sup>

*Universidad Nacional del Sur, Departamento de Geología  
Bahía Blanca, Argentina*

CARLOS E. GORDILLO

*Universidad Nacional de Córdoba, Facultad de Ciencias Exactas y Naturales  
Córdoba, Argentina*

AND DORA BEDLIVY

*Universidad Nacional de Buenos Aires, Facultad de Ciencias Exactas y Naturales  
Buenos Aires, Argentina*

### Abstract

Na-rich scapolite ( $Me_{20.1}$  to  $Me_{24.2}$ ) is the most abundant mineral filling veins near the roof of an epizonal quartz monzodiorite stock. No veins enter the wall rock. Small amounts of diopside, magnetite, sphene, calcite, chalcopyrite, apatite, quartz, and heulandite accompany the scapolite, which probably crystallized in open joints in a pneumatolytic-hydrothermal environment. For a scapolite of composition  $Me_{20.1}$ ,  $a = 12.059(1)$  and  $c = 7.583(1)\text{Å}$ . Measured refractive indices are  $\omega = 1.550$ ,  $\epsilon = 1.542$  for  $Me_{20.1}$  and  $\omega = 1.551$ ,  $\epsilon = 1.543$  for  $Me_{24.2}$ . Density is  $2.575\text{ g/cm}^3$ . Refractive index gives the best chemical composition value.

Scapolite is a common mineral, widespread in metamorphic terrains and in pneumatolytic-hydrothermally altered rocks. In both cases the formation of scapolite has been commonly regarded as a reaction process between rocks and fluids containing  $Cl^-$ ,  $CO_2$ ,  $SO_3$ , and  $Na^+$ , and less frequently as resulting from isochemical metamorphism (Shaw, 1960; Deer *et al.*, 1963).

Scapolite formed by precipitation from a fluid in an open space is uncommon, but it has been described as a vein and fissure mineral from a few localities, such as Pennsylvania (Tomlinson, 1943), the Swiss Alps (Shaw, 1960), and the Shetland Islands (Mykura and Young, 1969).

At Los Molles, Mendoza (Fig. 1), scapolite forms veins in vertical longitudinal joints developed in a quartz monzodiorite stock, with typical textures formed by primary crystallization.

According to the classification of Buddington (1959) the stock where the scapolite occurs is an epizonal pluton, intruded at very shallow depth in the

core of an anticline formed by gypsum beds (Aucuilco Formation), feldspathic sandstones (Tordillo Formation) of Kimmeridgian-Tithonian age, and black shales (Vaca Muerta Formation) of Tithonian-Berriasian age.

The stock is post-tectonic and belongs to a magmatic period that followed the major deformation of the Andean Mesozoic geosyncline at the end of Cretaceous. The age of the stock is stratigraphically estimated as Lower Tertiary.

The magma was poor in volatiles at the time of the intrusion. Neither granitization nor metasomatism has been observed in the wall rocks, and it was intruded forcefully, as is common in dry magmas, pulling apart the beds of the Tordillo Formation.

The scapolite veins vary in thickness from a few millimeters to 1.20 meters. The walls are plane, the contact between the scapolite veins and the quartz monzodiorite is sharp, and replacement in the wall rock has been observed only over 1–2 mm.

Scapolite forms acicular laths of various sizes, depending on the separation of the joint walls. In the thickest veins, scapolite crystals up to 10 cm in length have been found. The scapolite laths near the wall are

<sup>1</sup> Present address: Servicio Geológico Nacional—CONICET, Santa Fe 1548, 1060 Buenos Aires, Argentina.

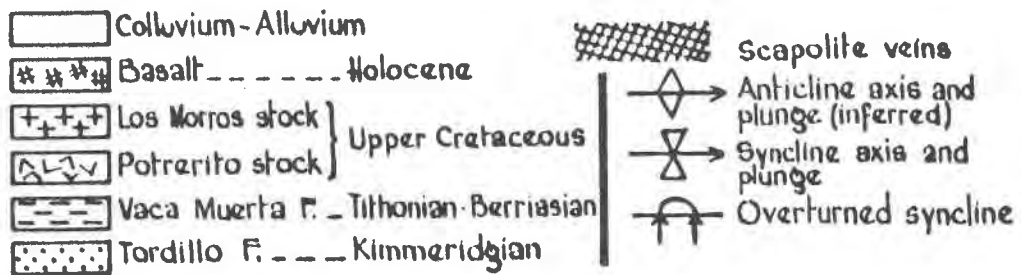
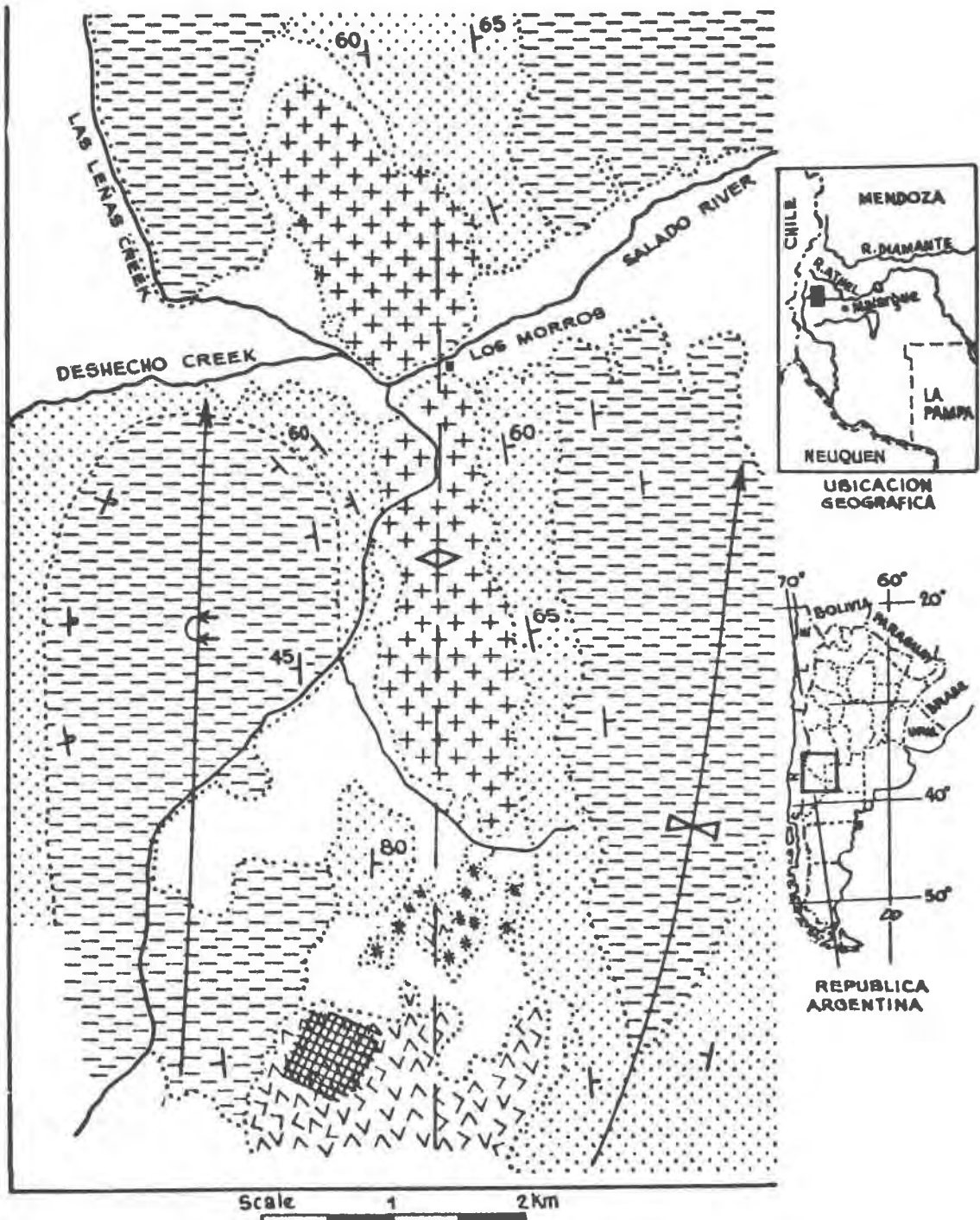


Fig. 1. Geologic map showing the pluton which contains the scapolite in the joints.

normal to it, but in the center of the veins they are arranged in radial groups. In the thinnest veins the crystals are parallel to the wall and their length ranges up to 30 mm.

Small amounts of diopside, magnetite, sphene, calcite, chalcopyrite, apatite, quartz, and heulandite accompany the scapolite.

The scapolite is grey, with a weak green tinge. Small acicular crystals are colorless. The density is

2.575(1) g/cm<sup>3</sup>; it was obtained by suspending a particle in a bromoform-alcohol mixture at 13.5°C. Refractive indices are given in Table 1.

Thermogravimetric analysis showed no loss of weight up to 1,000°C, and there was no change in the X-ray pattern after heating at this temperature.

Table 1 shows analyses of three scapolites from Los Molles which were performed by conventional methods. The meionite content is low as expressed by the ratio Ca/(Ca + Na + K) following Evans *et al.*, (1969), and varies between 20.1 and 24.2 percent Me. Therefore the Los Molles scapolites are marialite-rich.

Another feature of the scapolite from Los Molles is its low CO<sub>3</sub><sup>2-</sup> content, which is probably replaced by Cl<sup>-</sup> ions. Figure 2 represents the ratio (Cl + Na + K) versus (Ca + C + S), the straight line giving the mean values of the data by Deer *et al.* (1963) and Evans *et al.* (1969). The probability that Cl<sup>-</sup> ions fill in the deficiency of CO<sub>3</sub><sup>2-</sup> ions is reinforced by the fact that these scapolites lie quite near to the line, displaying a slight deficiency of (Ca + C ≠ S) relative to (Cl + Na + K).

The scapolite for the powder diagram was carefully selected from sample I, 20.1 percent Me. It was taken on a Philips diffractometer with Cu radiation and Ni filter using silicon as internal standard. The tetragonal cell parameters were calculated with a least-squares unit-cell refinement program (Job 9214; Appleman and Evans, 1973). Powder lines were checked with reflections from precession photographs, and 57 reflections were used for the input. The program closed after five cycles. The values are:

$$a = 12.059(1) \text{ \AA}; c = 7.583(1) \text{ \AA}; V = 1,103 \text{ \AA}^3.$$

The chemical composition of the scapolite from Los Molles (sample I) is almost identical with one from Gooderham, Ontario, used by Papike and Zol-tai (1965) and by Lin and Burley (1973) for their studies. The Gooderham scapolite has 19.4 percent Me, while ours has 20.1 percent Me. The X-ray parameters match well.

Determinations of chemical composition were made from cell parameters, cell volume, *d*-spacings of the lines *d*<sub>321</sub> = 3.06 and *d*<sub>822</sub> = 1.364, and the refractive indices using the determinative charts published by Ulbrich (1973). The refractive index yielded the best value. The *a* and *c* parameters gave a composition of 32 and 36 percent Me respectively, and the cell volume gave 31 percent Me. These are 10–15 percent too high, due perhaps to the fact that the percentage of 20 percent Me is almost beyond the scope of these

Table 1. Analyses of scapolite

Scapolite Analysis			
	I	II	III
SiO <sub>2</sub>	57.16	56.48	56.92
TiO <sub>2</sub>	0.04	0.09	0.05
Al <sub>2</sub> O <sub>3</sub>	21.88	22.23	22.14
Fe <sub>2</sub> O <sub>3</sub>	0.36	0.25	0.26
MnO	tr	tr	tr
MgO	0.05	0.08	n.d.
CaO	5.02	6.00	5.62
Na <sub>2</sub> O	10.10	9.47	9.52
K <sub>2</sub> O	1.46	1.43	1.32
H <sub>2</sub> O <sup>+</sup>	1.05	1.12	1.20
H <sub>2</sub> O <sup>-</sup>	0.05	0.05	0.06
CO <sub>2</sub>	0.10	0.12	0.08
SO <sub>3</sub>	0.38	0.41	0.38
Cl	3.32	3.25	3.45
Total	100.97	100.98	101.00
O=Cl	0.73	0.70	0.76
TOTAL	100.24	100.28	100.24
ω	1.550	1.551	1.551
ε	1.542	1.543	1.543

Numbers of ions on the basis of 12 (Si, Al)

Si	8.275	12	8.202	12	8.232	12
Al	3.725		3.798		3.767	
Ti	0.004		0.009		0.005	
Fe	0.040		0.028		0.028	
Mg	0.010		0.017		—	
Ca	0.778	3.93	0.933	3.91	0.870	3.81
Na	2.830		2.661		2.664	
K	0.269		0.265		0.243	
H	1.013		1.084		1.156	
C	0.020		0.023		0.016	
S	0.042	0.87	0.044	0.86	0.042	0.90
Cl	0.812		0.798		0.843	
% Me	20.1		24.2		23.0	
% Me =	$\frac{\text{Ca}}{\text{Ca} + \text{Na} + \text{K}} \times 100$					

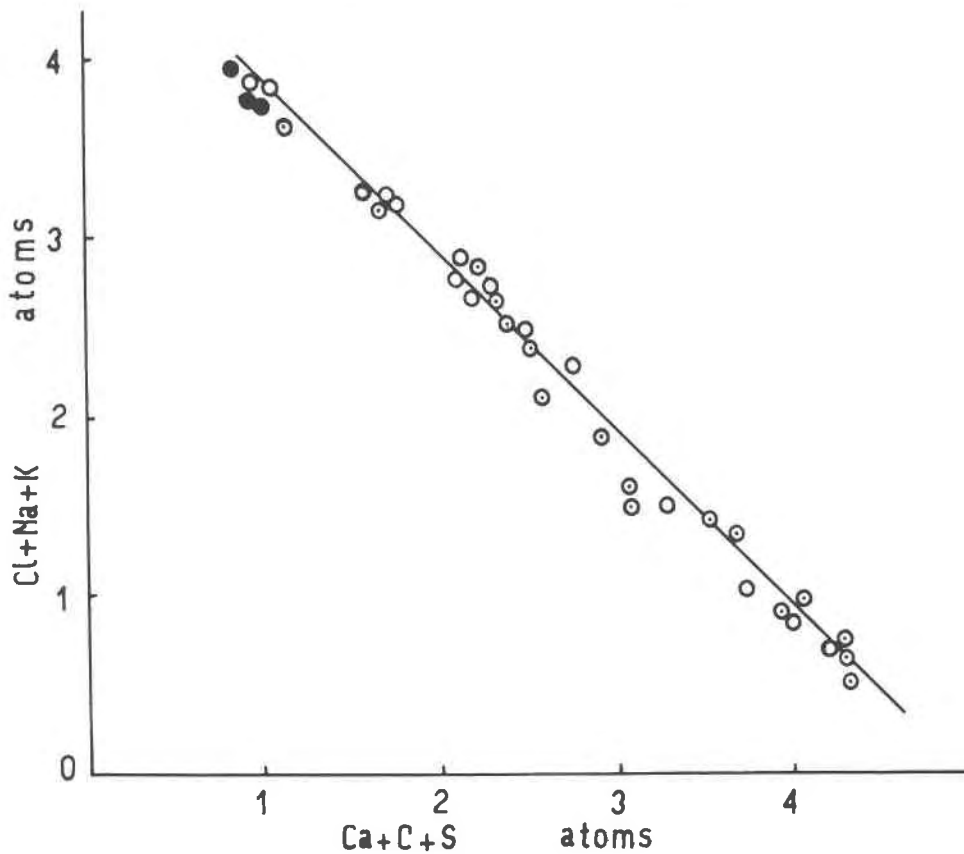


Fig. 2. Cl + Na + K versus Ca + C + S atoms, on a basis of Si + Al = 12.0. Circles after Evans *et al.* (1969); circles with a point after Deer *et al.* (1963); dots this study. The line is the average  $(Cl + K + Na) + (C + S + Ca) = 4.879$ .

charts. The spacings  $d_{321}$  and  $d_{822}$  gave 28 and 23 percent Me. The value determined from the refractive indices is 20 percent Me.

The scapolite from Los Molles probably originated in a pneumatolytic-hydrothermal environment by direct crystallization in open joints. Replacement phenomena are insignificant. The scapolite mineralization shows a refilling of longitudinal primary joints, formed during the cooling of the stock. There is no scapolite in the wall rocks, which are composed of marls and black shales. The diopside, magnetite, and sphene represent a high-temperature association. On cooling, the last mineral to crystallize is heulandite. The chemical composition of the Na and Cl-rich, Ca and S-poor scapolite does not conform with the geological character of its present environment, as it occurs in a quartz monzodiorite stock which is intruded into calcareous and gypsum sediments.

#### References

- Appleman, D. E. and H. T. Evans, Jr. (1973) Job 9214: Indexing and least-squares refinement of powder diffraction data. *Natl. Tech. Inf. Serv., U.S. Dept. Commer.*, Springfield, Virginia, Document PB 216 188.
- Buddington, A. F., (1959) Granite emplacement with special reference to North America. *Geol. Soc. Am. Bull.* 70, 671-747.
- Deer, W. A., R. A. Howie and J. Zussman (1963) *Rock Forming Minerals*, Vol. 4, *Framework Silicates*. Longmans, Green and Co. Ltd. 435 p.
- Evans, B. W., D. M. Shaw and D. R. Haughton (1969) Scapolite stoichiometry. *Contrib. Mineral. Petrol.* 24, 293-305.
- Lin, S. B. and B. J. Burley (1973) Crystal structure of a sodium and chlorine-rich scapolite. *Acta Crystallogr. B29*, 1272-1278.
- Mykura, W. and B. R. Young (1969) Sodic scapolite (dipyre) in the Shetland Islands. *Rep. Inst. Geol. Sci.* 69/4, 8 p.
- Papike, J. J. and T. Zoltai (1965) The crystal structure of a marialite scapolite. *Am. Mineral.* 50, 641-655.
- Shaw, D. M. (1960) The geochemistry of scapolite. Part I and II. *J. Petrol.* 1, 218-285.
- Tomlinson, W. H. (1943) Occurrence of sodic scapolite at falls of French Creek, Pennsylvania. *Am. Mineral.* 28, 110-114.
- Ulbrich, H. H. (1973) Crystallographic data and refractive indices of scapolites. *Am. Mineral.* 58, 81-92.

Manuscript received, December 29, 1975; accepted for publication, May 7, 1976.