

Carlosturanite (not 'picrolite') from Taberg, Sweden

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ABSTRACT. The second occurrence of the asbestiform silicate carlosturanite is reported. The mineral occurs in Taberg, Sweden, and it was previously reported as 'picrolite', that is fibrous antigorite. Carlostruranite from Taberg is non-pleochroic, green in colour and has positive optical elongation. The unit cell parameters are $a = 36.55$, $b = 9.31$, $c = 7.27 \text{ \AA}$, $\beta = 101.05^\circ$. Based on the determined formula, $(\text{Mg}_{20.47}\text{Fe}_{0.59}\text{Mn}_{0.06}\text{Cr}_{0.01}\text{Ti}_{0.01})(\text{Si}_{11.68}\text{Al}_{0.28})\text{O}_{27.81}(\text{OH})_{34.19}\text{H}_2\text{O}$ carlosturanite can be expected to crystallize within the pure $\text{MgO-SiO}_2\text{-H}_2\text{O}$ system as a low-grade metamorphic mineral.

Because there are close similarities in structure and properties of carlosturanite and the picrolite variety of antigorite, their distinction requires careful attention to X-ray and electron diffraction patterns and chemical compositions. The present identification of the Taberg specimen as carlosturanite puts a lower limit of 33.7 \AA to the known range of a parameters of antigorite.

KEYWORDS: carlosturanite, picrolite, antigorite, asbestiform minerals, Taberg, Sweden.

CARLOSTURANITE is a rock-forming silicate. The mineral was first reported from Sampeyre, Val Varaita, Italy (Compagnoni *et al.*, 1985), where it occurs as a low-grade metamorphic phase in a network of veins that cross-cut the antigorite serpentinite. From several points of view, carlosturanite strongly recalls the serpentine minerals; in fact, it is fibrous, monoclinic Cm , with $a = 36.70$, $b = 9.41$, $c = 7.291 \text{ \AA}$, $\beta = 101.1^\circ$. Serpentine minerals have $b \approx 9.3$ and $c \approx 7.3 \text{ \AA}$ and the antigorite varieties have long a axes, sometimes in the region of 36 \AA (Zussman *et al.*, 1957). The structural formula of carlosturanite is $M_{21}T_{12}O_{28}(\text{OH})_{34}(\text{H}_2\text{O})$, with M indicating octahedral cations and T indicating tetrahedral cations. The comparable serpentine formula would be $M_{21}T_{14}O_{35}(\text{OH})_{28}$. It can be seen that on the basis of the same number of octahedral cations the total number of oxygens is

the same (63) and the chemical difference is that carlosturanite has fewer T ions and more hydrogen.

Mellini *et al.* (1985) proposed a structure model for carlosturanite that was consistent with its chemical and physical properties. In their study, electron microscopy was more useful than X-ray diffraction because of the specimen's finely fibrous nature and somewhat disordered structure. The structure model was derived from the idealized parent structure of flat-layer serpentine (Wicks and Whittaker, 1975; Mellini, 1982), that is, the crystal structure of carlosturanite would be based on the same octahedral sheet that occurs in 1:1 trioctahedral layer-silicates, whereas the tetrahedral sheet would be modified. In particular, ordered silicon vacancies and substitution of hydroxyl anions and water molecules for oxygen atoms would produce tetrahedral strips that consist of three four-repeat single-crankshaft chains. This model took into account the water rich, silicon-poor chemistry of carlosturanite with respect to serpentine. It led to the prediction of the existence of a polysomatic series of serpentine-like minerals (inophite), and a few of these structures were actually found as faulted lamellae within carlosturanite.

The possible petrological importance of carlosturanite led us to enquire whether similar material had previously been found elsewhere, perhaps escaping completely correct recognition due to the difficult task of identification of the serpentine minerals (Whittaker and Zussman, 1956; Wicks and Zussman, 1975) and the similarities between them and carlosturanite (physical appearance, chemistry, cell parameters). Long-fibre 'serpentine', silicon-poor and water-rich 'serpentine', or large unit-cell 'serpentine' seemed to be worth further attention in this respect. By this note, the identification of 'picrolite' from Taberg as carlosturanite is

reported, together with the most important properties for this second occurrence.

Occurrence and description. In the present investigation we re-examined the original specimen (C.TW.2915 'picrolite, Taberg, Sweden') studied by Whittaker and Zussman (1956) and by Chapman and Zussman (1959). It was supplied (courtesy Dr S. O. Agrell) from collections of the Department of Earth Sciences, University of Cambridge.

The specimen is green in colour and looks like a splintery serpentine-like mineral. Its specific gravity, as determined by the heavy liquid method, is 2.68. When crushed, this material produces fibre bundles, elongated along [010], and further crushing leads to thin laths with excellent (001) cleavage. The mineral is non-pleochroic and has positive elongation with $\gamma \approx 1.54$. This value is low compared with γ for carlosturanite from Sampeyre (1.60) and this may be explained by the latter having higher FeO and TiO₂ content. The fact that γ is lower than that for antigorites may also be related to relative contents of Fe, Ti, etc., but in addition the presence of more structural OH and H₂O would be expected to have this effect.

Diffraction data. The X-ray powder diffraction pattern closely fits the corresponding pattern for carlosturanite from Sampeyre; the reflections were used to refine the unit cell parameters, and their values are $a = 36.55$, $b = 9.31$, $c = 7.27 \text{ \AA}$, $\beta = 101.05^\circ$ (cf. 36.70, 9.41, 7.291 \AA , 101.1° for the Sampeyre specimen).

The powder patterns from antigorites and carlosturanites, although distinguishable in detail, bear similarities, as would be expected. Difficulties in comparison arise because of (a) structural disorder and (b) the large a cell parameter. Disorder, leading to weaker and broader reflections, can occur through layer displacements, chain width errors in carlosturanite (mixed polysomes), and errors in the period of the alternating wave structure in antigorite. Even without such effects, unambiguous indexing and cross-correlation of peaks is very difficult purely because of the large and variable a parameter for each mineral. For the latter reason, distinctions are better sought at low Bragg angles.

X-ray 'single-crystal' methods for characterization and distinction are subject to similar difficulties through the effects of disorder and the large a parameters, but also because specimens of carlosturanite and some antigorites are finely fibrous and give diffraction patterns with rotational symmetry and many closely spaced spots on the layer lines.

The above difficulties are overcome when electron optical methods are used since the diffraction patterns are produced from single crystals in similar orientations [laths on (001): $a^* b^*$ patterns].

These can be more readily compared and the values of a^* can be determined. Electron optical methods have been fruitful for studies of serpentine-like minerals in general since they tend to consist of poorly crystallized and often heterogeneous material (Zussman *et al.*, 1957; Brindley *et al.*, 1958; Chapman and Zussman, 1959; Yada, 1967, 1971, 1979; Cressey and Zussman, 1976; Cressey, 1979; Thomas *et al.*, 1979; Veblen and Buseck, 1979; Jiang and Liu, 1984; Mellini, 1986).

Work with lattice images has become fairly common recently. Probably the first lattice fringe resolution in a mineralogical study was that by Brindley *et al.* (1958) on the serpentine antigorite; high resolution was not attainable at that time but was also not required because the fringe spacings were so large (generally $> 33 \text{ \AA}$). Further work by Chapman and Zussman (1959) on 'picrolite' from Taberg, Sweden, showed the occurrence of 16.8 \AA fault lamellae within a 19.1 \AA matrix. At that time, 'picrolite' from Taberg was identified as fibrous antigorite. However, as stressed by Chapman and Zussman (1959), these periodicity values are quite unusual for antigorite, that is known to be characterized by superlattice periodicities within the 33.7–109 \AA range (Zussman *et al.*, 1957). Also, the low periodicity is perhaps less compatible with the expected curvature radius for corrugated layers, that is approximately 65–85 \AA (Zussman, 1954; Whittaker, 1957; Kunze, 1961). Fortunately, after the recent characterization of carlosturanite, these difficulties can be overcome by hypothesizing that 'picrolite' from Taberg is actually carlosturanite. In fact, the 19.1 \AA and 16.8 \AA periodicities given by Chapman and Zussman (1959) for 'picrolite' strongly recalled the 18 \AA $d(200)$ interplanar spacing of carlosturanite, S_5X , and the 15.5 \AA $d(100)$ of the S_4X polysome [$S = \text{serpentine} = M_3T_2O_5(OH)_4$; $X = M_6T_2O_3(OH)_{14} \cdot H_2O$].

An $a^* b^*$ electron diffraction pattern typical of picrolite from Taberg is shown in fig. 1. This pattern closely matches fig. 1a of the paper by Mellini *et al.* (1985). No a periodicity other than 36 \AA occurs as sharp spots in the patterns given by several fibres; however, faulted a periodicities other than 36 \AA , or the halved value 18 \AA , were reported by Chapman and Zussman (1959), and lattice fringes with 15 \AA spacing have once more been observed in the present study. Some streaking (parallel to a^*) of spots in fig. 1 is probably related to disorder produced by chain-width errors.

The distribution of spots along a^* rows is recognizably different for antigorite and carlosturanite. For antigorite (see Brindley *et al.*, 1958) closely spaced spots tend to cluster around positions where normal serpentine ($a = 5.3 \text{ \AA}$) spots would be, and there are fewer and weaker spots

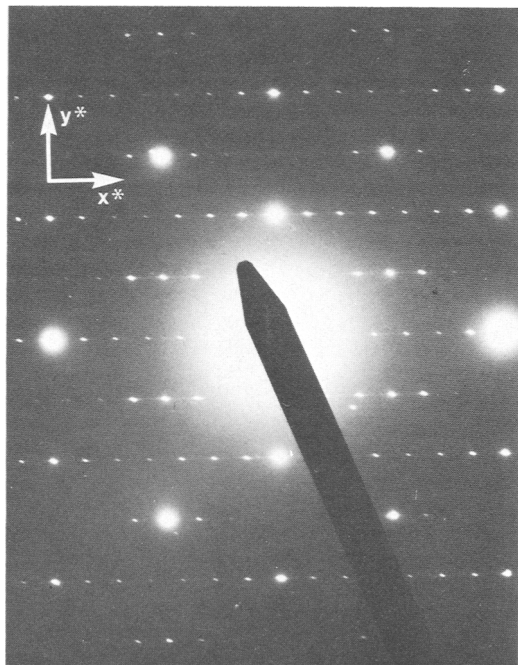
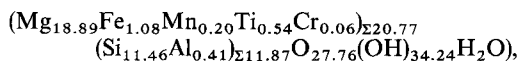


FIG. 1. $a^* b^*$ electron diffraction pattern of carlosturanite from Taberg.

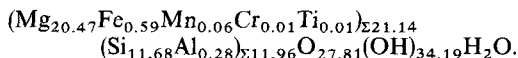
elsewhere. For carlosturanite, the intensities of spots follow a more or less continuous modulation and the clustering effect is not evident.

Crystal chemistry. The results of qualitative chemical analysis, performed by energy dispersive spectrometry in the transmission electron microscope, indicated abundant Mg, Si and Fe, with possible low quantities of Al, Mn, Ti, V or Cr. Quantitative data were gathered by an electron microprobe analyser, using 15 kV accelerating voltage, 3–4 μm spot size, crystal spectrometer for transition elements and Si(Li) detector for the other elements. These data, and the atomic ratios computed on the basis of 63 oxygens and also for 45 anhydrous oxygen atoms are reported in Table I, together with the average analysis given by Compagnoni *et al.* (1985) for the Sampeyre specimen. The difference between the probe analysis total and 100 per cent was taken to represent H_2O^+ .

Up to now, only two reports on the occurrence of carlosturanite are available. The holotype carlosturanite from Sampeyre has the following crystal chemical formula



whereas carlosturanite from Taberg has the formula



Both the Sampeyre and the Taberg formulae closely fit the expected ideal formula $M_{21}T_{12}O_{28}(\text{OH})_{34}(\text{H}_2\text{O})$. However, significant chemical differences between the Taberg and Sampeyre specimens exist, the most important feature being the different transition element content. Indeed, whereas the Taberg specimen almost approximates to a pure Mg and Si composition, although with low Fe and Al contents, more abundant chemical substitutions occur in the Sampeyre specimen. Such differences can explain differences in colour, but more importantly, the almost pure composition of the Taberg specimen indicates that transition elements are not necessary components of carlosturanite, and this phase may be quite well expected to crystallize within the pure $\text{MgO-SiO}_2\text{-H}_2\text{O}$ system. Within this system, from a chemographic point of view, carlosturanite differs from chrysotile and lizardite in just the opposite way that antigorite does. Antigorite, which is not strictly a serpentine polymorph, differs from the serpentine stoichiometry by slightly lower magnesium and water contents (Page, 1968; Whittaker and Wicks, 1970). By contrast carlosturanite shows higher magnesium and water contents. These chemical relationships are depicted in fig. 2, where the whole theoretical field for the inophite polysomatic series has also been indicated. It might be suggested that these chemographic relationships could be correlated with different metamorphic grades. As antigorite is normally characteristic of higher grade terrains (e.g. Trommsdorff, 1982), carlosturanite would be related with lower metamorphic grade with respect to the serpentine polymorphs. Such an assumption would be in keeping with the previous observations by Compagnoni *et al.* (1985), who found micrometric, pseudomorphic brucite and chrysotile after carlosturanite.

Petrological significance of carlosturanite. During the first study of carlosturanite, Compagnoni *et al.* (1985) indicated 250–300°C and 2 kbar water pressure as the possible environment where carlosturanite from Sampeyre was formed. Based on the Ti partitioning between carlosturanite and the paragenetic minerals, they hypothesized the possible existence of chemical controls by such cations as Ti on the formation of the mineral. However, this last assumption does not hold any more when the new data from Taberg are considered. Instead, the P - T environment in which carlosturanite was probably formed in the Sampeyre serpentinite is indicative of a very large group of possible occurrences in retro-metamorphosed mafic and

TABLE I. *Chemical data for carlosturanite from Taberg and Sampeyre*

Taberg		Sampeyre				
Wt. %	Atoms per formula unit		Wt. %	Atoms on basis of 63(O)		
	On basis of 45(O) anhydrous	On basis of 63(O)				
SiO ₂	36.65	11.70	11.68	35.53	11.46	11.87
Al ₂ O ₃	0.74	0.28	0.28	1.07	0.41	
TiO ₂	0.02	0.01	0.01	2.24	0.54	20.77
Cr ₂ O ₃	0.04	0.01	0.01	0.24	0.06	
FeO	2.20	0.57	0.59	4.03	1.08	18.89
MnO	0.21	0.06	0.06	0.72	0.20	
MgO	43.11	20.51	20.47	39.28	18.89	
CaO	n.d.			—	—	
K ₂ O	n.d.			—	—	
NiO	n.d.			—	—	
H ₂ O+	82.97			83.11		
	17.03*		H = 36.19	16.85		H = 36.24
Total	100.00					

* By difference. n.d. not detected.

ultramafic rocks. Furthermore, as Ferraris and co-workers (priv. comm., 1984) have recently found a third and a fourth occurrence of carlosturanite, both of them from the Western Alps, there is increasing evidence for the widespread occurrence of this mineral.

It is of interest to note that although inophite polysomes other than S_5X , carlosturanite itself, have been observed as fault structures, they have never been observed as discrete phases. As yet, four different occurrences for carlosturanite are known, but since the different polysomes probably require quite similar chemical and environmental conditions, there is no clear explanation as to why carlosturanite would be favoured over the others.

Conclusions. The 'picrolite' from Taberg, once thought to be an antigorite with unusually short a

repeat is shown to be carlosturanite. Distinction between serpentine minerals and members of the carlosturanite family (inophite series) is difficult by X-ray diffraction and is better made by electron diffraction and microprobe analysis, although the latter technique would probably not resolve the different S_nX polysomes of the inophite series, if these are present. With regard to picrolites generally, other specimens may indeed be varieties of antigorite, but it seems wise to give these further attention. Although this paper does not directly deal with antigorite, our results have important implications for this mineral. It is well known that the a parameter of antigorite can assume different values within a series, owing to the wavy nature of its structure and the possible different numbers of silicon tetrahedra within a full wavelength (Zuss-

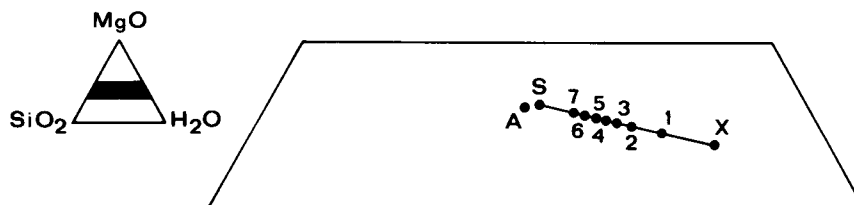


FIG. 2. Chemical composition across the inophite polysomatic series. The digit indicates the n value of the S_nX polysome. S is serpentine, A antigorite and X the hypothetical hydro-sorosilicate assumed as second end-member of the polysomatic series.

man, 1954; Kunze, 1961). These values typically range from 33.7 to 109 Å (Zussman *et al.*, 1957) and the unusual 19.1 and 16.8 Å values must be definitely ruled out, as they refer to carlosturanite, and not to antigorite.

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