cracks. Griffin and Murthy (*6*) reported inclusions of both rutile and garnet in these samples, with rutile by far the predominant. This suggests that most of the uranium in the Bultfontein clinopyroxenes may be associated with acicular inclusions of rutile. Two grains from the Bultfontein locality had a few individual tracks in the matrix, which gives an estimated matrix concentration of $\lesssim 0.01$ ppb. The Roberts-Victor samples were somewhat more homogeneous with the three grains studied showing apparently randomly distributed tracks; estimated matrix concentrations in these samples are 1 to 2 ppb. A large number of the tracks in one of the grains, however, were concentrated along cracks resulting in a crack concentration of uranium, very much greater than 0.1 ppb.

The estimates of total uranium concentrations, however, may be very inaccurate in cases where heterogeneous distributions occur. These should be treated as order-of-magnitude estimates only. Apart from the obvious sampling problem, the track densities in clusters are frequently so high as to be unresolvable. In the case of cracks that propagate into the interior, an unknown amount of surface area is etched and the estimates are especially unreliable. In addition, cracks may contain contaminants introduced by the polishing. Finally, cracks are also sources of dislocation etch lines that can be confused with fission tracks.

Limited sampling of separated clinopyroxenes from four different eclogites indicates that the uranium in these minerals may occur as random atoms uniformly distributed throughout the crystal, as clusters of atoms occurring at points or lines within the crystals, or as contaminants along cracks and flaws in the grains. The concentration of uniformly distributed uranium varies by a factor of approximately 1000 among the clinopyroxenes from the four eclogites studied. The total uranium present in whatever form appears to vary by a factor of about 100. The latter conclusion is less certain because of difficulty in estimating total uranium by this technique when the concentration is not homogeneous. There is some suggestion in the data that the amount of uniformly distributed uranium increases in the clinopyroxenes as the total uranium concentration increases.

The ratios of K to U in these clinopyroxenes are noteworthy. Using the potassium values reported by Griffin and Murthy (*5*) we obtain K/U ratios of about 3×10^3 for the samples from Salt Lake Crater and ratios of about 10^6 to 10^7 for the Roberts-Victor and Bultfontein samples. Even if the heterogeneously distributed uranium were included, the latter two samples would still show high K/U ratios of about 10^6. This suggests that, although there is a broad coherence between potassium and uranium in many surface terrestrial materials as indicated by the relatively constant K/U ratio of 10^4 for such materials (*9*), it may be possible to fractionate potassium and uranium in some minerals important in the upper mantle.

In terms of the concentrations of uranium in the oceanic upper mantle, it may be significant that the clinopyroxenes from the only oceanic locality studied (Salt Lake Crater) contained both the largest concentration of uranium and the most uniform uranium distribution. This investigation indicates, however, that the total uranium concentration in clinopyroxene (and, presumably, in other minerals) may be misleading to one who is estimating the amount of uranium in their source regions. If the total uranium concentrations are less than a few parts per billion, much if not most of the uranium may occur as contaminants along cracks, in microinclusions, or as grain boundary films. The reported lability of potassium in these minerals (*5*) suggests that the same is true for this element. We suggest that the abundance of potassium and uranium and the K/U ratio of a substantial fraction of the earth's inventory of these elements remains poorly known. Models of heat flow for the earth based on reported concentrations of these heat-producing elements in either separated minerals or whole-rock samples from eclogites, ultramafic rocks, or chondritic meteorites must be considered tenuous until the amount and source of contaminant uranium and potassium have been determined in these rocks and meteorites.

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Pecoraite, $Ni_6Si_4O_{10}(OH)_8$, Nickel Analog of Clinochrysotile, Formed in the Wolf Creek Meteorite

Abstract. *Pecoraite is a new phase in the natural system H_2O-NiO-MgO-SiO_2, the nickel analog of clinochrysotile. It occurs in cracks in the Wolf Creek meteorite in Australia where it was formed under hydrothermal conditions. Particles of pecoraite are very small curved plates which have begun to coil; some have achieved spiral form.*

A green mineral of the serpentine group, rich in nickel, was described (*1*) from the Wolf Creek meteorite in the desert of Western Australia. This mineral is the nickel analog of the well-known magnesium silicate, clinochrysotile.

The new mineral is named pecoraite after Dr. William T. Pecora, Director of the U.S. Geological Survey, in recognition of his contributions (*2*) to the mineralogy and geology of nickel silicate deposits in North America and South America (*3*).

Pecoraite occurs as green grains, 0.1 to 5 mm in diameter, that fill cracks in the Wolf Creek meteorite. The color is the "Oriental Green" of Ridgway (*4*). The phase is weakly doubly refracting and has indices of refraction varying from 1.565 to 1.603 depending on the quantity of adsorbed water. A sample of pecoraite dried over magnesium perchlorate to remove the excess water has a mean index of refraction close to 1.650. The specific gravity of the pecoraite containing adsorbed water is 3.08_4.

A carefully purified sample (0.1 g) contained in weight percentages: SiO_2, 31.0; NiO, 51.5; FeO, 0.7; MgO,

Table 1. Results of x-ray powder diffraction of pecoraite with copper radiation and nickel filter.

Probable *h k l*	Observed *d* (Å)	Intensity ($\sqrt{2}$ scale)
002	7.43	8
020	4.50	5
004	3.66	6
130	2.620	5
$20\bar{2}$	}	Diffuse band
202	2.447	4
204	P*	Diffuse
060	1.529	6
$40\bar{2}$	1.303	Diffuse band

* Present but not measurable.

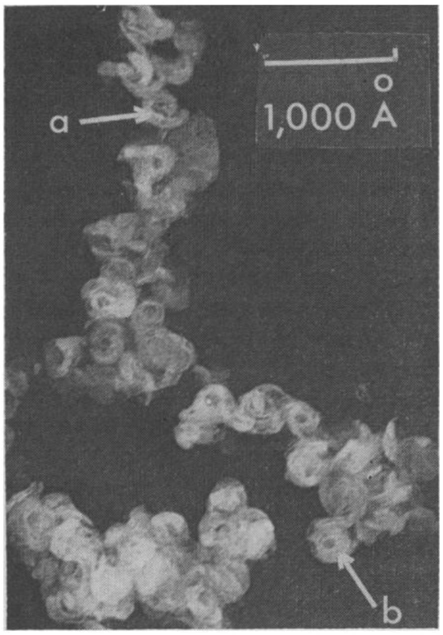

Fig. 1. Electron micrograph of pecoraite showing aggregates of curved plates: *a*, coils; *b*, spirals.

0.5; Al_2O_3, 1.4; H_2O^+, 9.7; H_2O^-, 4.1; CaO, 0.4; a total of 99.3 percent. Deducting the CaO value, which is equivalent to about 1 percent of the phosphate cassidyite (*1*), and the adsorbed water (H_2O^-) the formula becomes (*5*)

$$[Ni_{5.41}Mg_{0.10}Fe^{2+}_{0.08}Al_{0.22}][Si_{4.05}]O_{10}(OH)_8$$

The x-ray powder diffraction pattern (obtained with copper radiation and nickel filter) is very similar to that of clinochrysotile, except for the line broadening due to the extremely fine grained nature of the material (Table 1). Indexing is by analogy with data for clinochrysotile of Whittaker and Zussman (*6*). Electron microscopy confirms the small particle size and shows that some of the particles form as curved plates; others have started to coil and some have formed complete spirals (Fig. 1). The average thickness of the plates [calculated from line-breadth measurements on the x-ray powder photographs and diffractometer traces with the equation of Wilson (*7*)] is 74 Å and 68 Å, respectively. Direct measurement on the electron micrograph gives 70(±5) Å in those areas free of overlapping segments of coils and spirals. This value will be determined more accurately when high-resolution stereo pairs are available.

Pecoraite is associated with major quantities of maghemite and goethite and lesser amounts of cassidyite, reevesite, and adventitious quartz blown into the cracks.

Pecoraite was formed during the mechanical and chemical disintegration of the meteorite fragments as they lay on the desert floor. The cyclical process of extreme heating during the day and slower cooling after sundown and at night, integrated over a long period of time, caused the meteorite fragments to crack. Sand grains blown into the cracks helped to widen them and were themselves crushed. Rainfall during the monsoon season became entrapped in the cracks, and on heating in the morning sun the cracks behaved like a whole system of small hydrothermal bombs in which pecoraite was slowly formed by the reaction of nickel and silica. At the same time goethite, maghemite, and the other phases were formed as the iron alloy was decomposed.

We anticipated from crystal chemical considerations that nickel analogs of many magnesium silicates should exist under natural conditions, and many poorly characterized nickel silicates have been described. Pecoraite is the second naturally occurring hydrous nickel silicate to be established firmly; the first was pimelite, the nickel member of the montmorillonite series (*8*). Ostrowicki (*9*) has found a phase with a *d*-spacing of 9.9 to 10.4 Å. We anticipate that others will be found.

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Azurin: X-ray Data for Crystals from Pseudomonas denitrificans

Abstract. *Azurin, a blue-colored copper protein, from a soil bacteria,* Pseudomonas denitrificans, *has been crystallized and its molecular weight of 16,000 was confirmed by means of x-ray diffraction.*

Azurins are the simplest copper proteins known. They contain only one copper atom per molecule and have low molecular weight (about 14,000 in a single polypeptide chain) (*1*). However, their optical absorption and electronic spin resonance structure are almost identical to much more complex copper proteins, such as ceruloplasmin (*2*) which contains eight copper atoms per molecule, with a molecular weight of about 140,000 and eight subunit polypeptide chains (*3*). The purpose of this study is to obtain detailed structural data applicable to all copper proteins and their biological roles.

We used azurin from *Pseudomonas denitrificans* (a soil bacteria) which was purified by the procedure of Suzuki and Iwasaki (*4*). The protein was not pure, as indicated by the absorption spectrum. Nevertheless, azurin could be crystallized in three different ways. (i) Slow addition of solid ammonium sulfate with slow evaporation of water gave both discrete and continuous changes in ammonium sulfate concentration. (ii) A freshly prepared hot gelatin solution (0.7 percent by weight, U.S.P. gelatin in distilled water) was allowed to cool and solidify in the bottom of a U-shaped polyvinylchloride tube, and a saturated solution of ammonium sulfate was placed at one side of the gelatin plug to diffuse across to the azurin solution placed on the other side. Azurin crystals formed in a few days, and the crystals and the liquid