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ZOISITE-RUTILE ROCK FROM LOS ANGELES COUNTY, CALIFORNIA

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ABSTRACT

Small scattered pods of zoisite-rutile rock occur within one of two belts of en-echelon lenticular serpentinite bodies. The serpentinite is largely altered to a talcose rock and the bodies are rimmed by coarse-grained actinolite. The zoisite-rutile rocks are gradationally rimmed by a zoisite-sphene-serpentine assemblage, in turn grading out to a black serpentine rock with disseminated ilmenite. A country rock inclusion is also rimmed by a zoisite-talc-garnet assemblage. It is postulated that the zoisite-rutile assemblage formed within the serpentinite by metasomatic transfer of material derived from the alteration of the serpentinite and controlled by pressure differential within the serpentinite body.

INTRODUCTION

A rutile-bearing zoisite-serpentine rock in the Pelona Schist of northern Los Angeles County is associated with ilmenite- and sphene-bearing serpentine rock and occurs as inclusions within serpentinite. The serpentinite and associated rocks are exposed in several trenches and can be traced on the surface near the head of Spade Spring Canyon, north of U. S. Highway 6 (Fig. 1).

Two WSW–ENE trending belts of serpentinite and associated rocks traverse the area. The rutile-bearing zoisite rock has been found only in the more northerly belt. The southerly belt, not fully shown in Fig. 1, is a nickeliferous talc-carbonate schist.

The serpentinite intrudes interbedded mica schist and feldspathic garnet-hornblende schist of the Pelona Schist. The predominant strike of the schist is WSW–ENE, and the rocks are folded with moderate dips. A general geological map of this area has been published (Jahns and Muehlberger, 1954). The petrography of a correlative of the Pelona Schist, known as the Rand Schist, is described in the monograph on the Randsburg Mining District (Hulin, 1925); a zoisite rock bearing superficial resemblance to that described herein is reported from the Rand Schist. Clinozoisite has been reported from San Francisquito Canyon in the Pelona Schist (Murdock and Webb, 1954).

The zoisite-rutile occurrence was brought to the writer's attention by Mr. R. A. Eaton of Saugus, California, and appreciation of his help, and that in the field of Mr. C. C. Huntington, is gratefully acknowledged. The assistance of Mr. B. W. Troxel, California Division of Mines, in locating the Randsburg occurrences is also acknowledged.

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Occurrence

The belt of serpentinite and related rocks in which the zoisite rock is found was traced along strike for over two miles. The individual serpentinite bodies have a maximum length of 300 feet and width of 50 feet. The bodies are pod-like; for example at locality 6 (Fig. 1), a 45-foot wide dike exposed in a trench narrows down to a 10-foot width within a strike distance of 75 feet. Although the serpentinite bodies strike in a general WSW–ENE direction, the strike of individual bodies ranges from WNW–ESE to NE–SW. Individual serpentinite bodies are separated either by country rock or their extension is marked by narrow actinolite-filled stringers. The serpentinite bodies apparently occur in an en-echelon manner along a WSW–ENE trending zone.

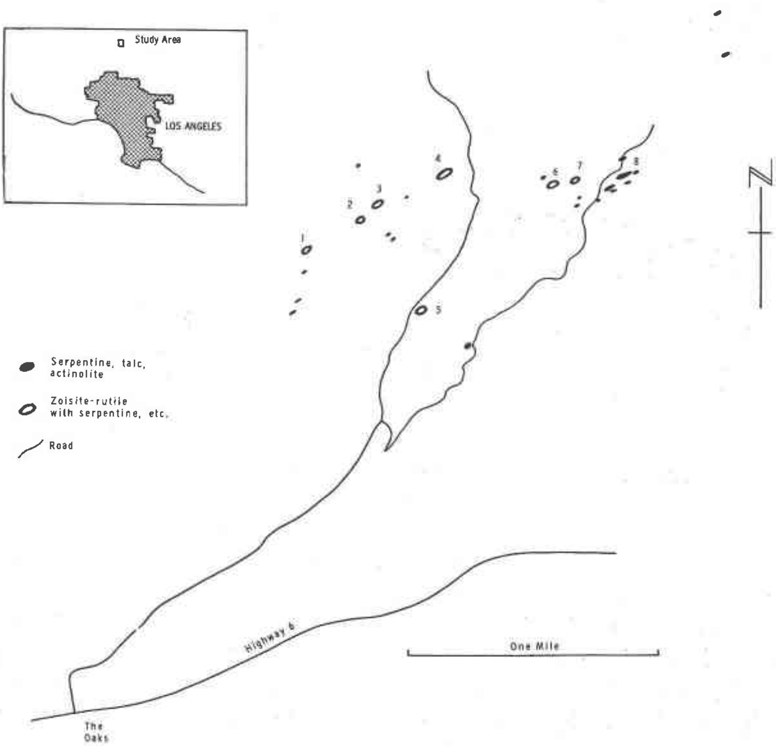

Fig. 1. Location and distribution of serpentinite and zoisite-rich rocks.

The serpentinite bodies have sharp and well-defined contacts with adjacent Pelona Schist without any visible wall-rock alteration. Measured contact dips vary from 45 degrees to 80 degrees, generally in a northerly direction. The margins of the serpentinite bodies are marked by a narrow zone, six inches to two feet wide, composed either of green coarse-grained actinolite, or actinolite crystals in talc schist. A generalized plan of a serpentinite body is given in Fig. 2.

The larger part of the serpentinite bodies consists of schistose, brown-weathering, talc-carbonate-serpentine rock. This rock typically is a fine-grained mosaic of antigorite and carbonate with talc lamellae and minor accessory sphene. Large carbonate porphyroblasts partly replaced by limonite occur in the rock; local rounded masses of carbonate up to one foot in diameter can be seen at locality 8 (Fig. 1).

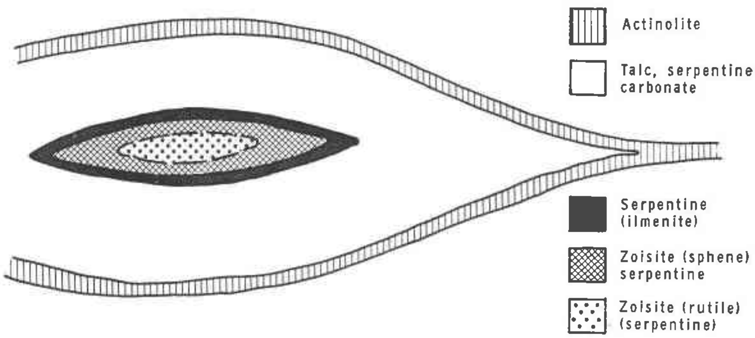

FIG. 2. Generalized plan showing relationship between zoisite-rutile rock and serpentinite body.

The rutile-bearing zoisite rock occurs as small pods or inclusions within the above described talc-antigorite rock. Locations of the zoisite rock exposures are marked in Fig. 1. The zoisite pods range in observed size from two to six feet in length, from one to two feet wide and from one to four feet high. In attitude, they generally parallel the walls of the serpentinite bodies. Typically, the pods are subrounded in shape and are zoned with an outer zone of serpentine with minor zoisite, gradationally followed by the central zoisite-rich rock (Fig. 2).

The zoisite pods are invariably surrounded by a zone or shell of black, fine-grained serpentinite, a few inches to several feet in thickness. This serpentinite is banded and is composed of fine-grained antigorite with accessory ilmenite; the ilmenite occurs as small irregular-shaped clots disseminated through the rock.

Passing inwards into the zoisite pod, scattered elongate crystals of zoisite up to a half inch in length occur in the black serpentinite. The antigorite matrix of this rock is slightly coarser than that in the surrounding serpentinite, and the accessory minerals include leucoxene and sphene as well as ilmenite. The rock is nonfoliated. Toward the center of the zoisite pods, zoisite becomes more abundant and forms an irregular network of platey crystals within an antigorite matrix. Individual crystals are commonly a half inch to one inch in length. The identity of the zoisite was confirmed by means of *x*-ray powder diffraction data. Zoisite constitutes up to 50% of the rock. Partial chemical analyses are given in Table I.

The titanium mineral varies in character passing into the pods. In the surrounding serpentinite it is ilmenite which, with increase of zoisite content, is altered to white leucoxene, in turn partly replaced by sphene. The most common titanium mineral in the zoisite pods is sphene, occurring both as irregular masses and as poorly developed crystals. However in the center of the pods, rutile occurs both as euhedral crystals and as irregular

TABLE I. PARTIAL ANALYSIS OF ZOISITE-RUTILE ROCK AND SURROUNDING SERPENTINITE. SAMPLES TAKEN THREE FEET APART, LOCALITY 7

Per Cent	Serpentinite	Zoisite-Rutile rock
CaO	0.38	11.4
MgO	24.7	7.7
TiO_2	1.40	1.39
Fe	5.22	4.11

masses, and locally constitutes 5–10% of the zoisite rock. The irregular masses of rutile in part rim sphene segregations and, in part, replace leucoxene. Euhedral rutile crystals are either scattered through the rock or occur in narrow zones associated with carbonate. The titanium and iron content of typical zoisite rock is compared with surrounding serpentinite in Table I.

A large inclusion of country rock occurs in serpentinite at locality 8. The broken schistose rock consists of bands of small hornblende crystals, with some biotite, and granular quartz in an equigranular anhedral matrix of anorthoclase. Small garnets occur in the hornblende-rich streaks. The visible subrounded end of the inclusion is approximately six feet wide, and has a strike length of 15 feet. The inclusion is rimmed by a six inch to eighteen inch wide zone of a green, fairly massive rock which contains pink garnets as well as zoisite crystals in a matrix of fine-grained antigorite and talc with accessory ilmenite and minor sphene.

The euhedral pink garnets, up to one-quarter of an inch in diameter, contain inclusions of zoisite. The garnets are not zoned. However *x*-ray analysis of a group of crystals from one rock sample showed the presence of two garnets with respective unit cell dimensions of $a = 11.655$ and 11.635 Å. Garnets with similar cell size have been reported from meta-anorthosite where, although both garnets were principally composed of the almandite and grossularite molecules, the smaller unit cell contained the greater amount of the pyrope molecule (Levin, 1950).

The garnet-bearing rock is surrounded by a one- to two-foot wide zone of zoisite-bearing serpentine rock free of garnets. Pseudomorphs of antigorite after garnet occur in this rock. In turn, the zoisite-bearing rock is surrounded by black serpentinite similar to the other occurrences described above.

Rand Schist

The Rand Schist consists of mica, albite, and amphibole schists with minor quartzite and limestone (Hulin, 1925). Local talc-actinolite schists have been worked as a source of talc (Troxel and Morton, 1962). One such occurrence examined consisted of steeply dipping talc-actinolite schist, associated with talc schist, with rusty carbonate porphyroblasts and with slivers and schlieren of black serpentinite. This particular occurrence is similar to the occurrences in the Pelona Schist.

The zoisite rock in the Rand Schist crops out on the side of a small NNW trending gully, approximately two miles SSW of Randsburg in the northwest quarter, Section 11, T30S, R40E. The rock is conformable and in sharp contact with schist. The rock is composed of plates of zoisite up to one inch in length in an antigorite-talc matrix without any accessory titanium minerals. Two large outcropping areas, one 200 feet long by 50 feet wide, are probably the same horizon folded with dips as low as 15 degrees. The rock also is cut in mine workings a quarter of a mile to the south. No serpentine or talc-carbonate schists occur with this zoisite rock.

Genesis

Although the above description is merely intended to be a record of an unusual occurrence of rutile, the rather well-exposed field relationships dictate some discussion of the origin of the zoisite-rutile rock. Pertinent facts include the occurrence as small pods in serpentinite bodies, the predominant alteration of the serpentinite to a schistose talc rock, with however the apparent preservation immediately adjacent to the zoisite pods of typical black banded serpentinite. In addition, the content of zoisite is gradational from the black serpentine rock into the zoisite-rich pod, and furthermore, the zoisite crystals occur in an interlocking texture somewhat resembling the ophitic feldspar-lath texture, in marked contrast to the directed or schistose texture within the altered serpentinite. Finally, the titanium mineral grades from ilmenite to sphene to rutile.

The serpentinite bodies are presumed to be of ultrabasic origin. The zoisite-rich pods could have originated either by incorporation of zoisite rock within the serpentinite, by alteration of other country rock inclusions within the serpentinite, or by the alteration of the serpentinite itself. The presence of the assemblage zoisite-rutile and, in one case garnet, together with the change in titanium mineral from ilmenite through sphene to rutile suggests by analogy to similar parageneses in the Franciscan (Bailey *et al.*, 1964) that the mineral assemblage could be a result of relatively high pressure.

Zoisite-rich rocks occur in the Rand Schist and can be presumed to occur in the similar Pelona Schist. This zoisite rock is quite different in occurrence and accessory mineral content from the zoisite-rutile rock. Conceivably, however, this rock type could have been incorporated in serpentinite and with only relatively minor chemical adjustment give rise to the zoisite-rutile rock. Against this hypothesis of origin is the inclusion of country rock at locality 8 rimmed by zoisite rock, which suggests that the zoisite rock was actually formed within the serpentinite body.

If the zoisite rock formed within the serpentinite body then there is no conclusive evidence in these occurrences to differentiate between an origin by alteration of serpentinite or alteration of country rock. The features which support an origin from country rock include the difference in chemical composition between zoisite rock and serpentinite, the occurrence of the zoisite rock in only one of the two parallel belts of serpentinite, and the rim of garnet-bearing zoisite rock around the country rock inclusion, even though the altered zone is narrow and the transition abrupt. On the other hand, the gradation from serpentinite into zoisite rock suggests an origin by alteration of serpentinite.

The gradation in composition of the titanium mineral from ilmenite through sphene to rutile passing from serpentinite into the zoisite rock may be due either to a normal metamorphic gradient or to retrograde alteration. However the presence of sphene pseudomorphs after ilmenite, and rims of rutile around sphene, suggest a normal metamorphic sequence.

The question now arises of how can local areas of unfoliated rock with a mineral assemblage suggesting formation under conditions of high pressure, originate totally enclosed within schistose altered serpentinite which has many characteristics of low metamorphic grade. The enechelon lenticular nature of the serpentinite suggests that this rock was squeezed into available structural openings. It is postulated that if the upward flow of the serpentinite was arrested by lack of suitable structure, then build-up of pressure within any one lenticle or structural opening could cause a swirling flow which might in turn promote the development of vortexes or nodes which would be subjected to appreciable confining pressures, equal on every side, but not to lateral pressure. It is further postulated that the zoisite rock was formed at such locations and that the absence of similar rocks in the parallel serpentinite belt to the south could be due to lack of vertical confinement in this zone at the level of observation.

Finally, on the basis of the above argument, the writer favors a metasomatic origin for the zoisite-rutile pods with transfer of material derived from the alteration of serpentinite and controlled by pressure differential within the serpentinite body.

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