NOTES AND NEWS

THERMAL METAMORPHISM OF TILLITE AT ALTA, UTAH

BRONSON STRINGHAM AND MAX P. ERICKSON,
University of Utah, Salt Lake City, Utah.

The occurrence of tillite in Utah is well known from the findings of Blackwelder, Hintze, Eardley and others,[1] and many localities have been noted and the tillite described. In the Cottonwood-American Fork region 14 miles southeast of Salt Lake City, near the old ghost mining town of Alta, the tillite has been thermally metamorphosed by the Cottonwood granodiorite with the development of several interesting features.

GENERAL GEOLOGY

Calkins'[2] map of the Cottonwood-American Fork region includes the area where the specimens for this study were collected. Here, at the bottom of Little Cottonwood Canyon, the sedimentary rocks strike nearly north-south and dip steeply toward the east. The tillite is nearly a thousand feet thick and is interbedded in quartzite. The age of the tillite has been determined as late Proterozoic by workers who have studied the formation. To the west, the contact of the Cottonwood granodiorite, which trends generally north-south, is to be found several hundred feet below the bottom of the tillite next to quartzite. The Cottonwood granodiorite is a stock which outcrops in an area of about 25 square miles. The tillite can be traced several miles northward to Big

[1] Blackwelder, E., An ancient glacial formation in Utah: *Jour. Geol.*, **4.** 289–304 (1932).

——— Wasatch Mountains revisited (*abst.*): *Geol. Soc. Am., Bull.* **36,** 132–133 (1925).

Butler, B. S., Ore deposits of Utah: *U. S. Geol. Sur., Prof. Paper* **111** (1920).

———, and Loughlin, G. F., A reconnaissance of the Cottonwood-American Fork Mining Region, Utah: *U. S. Geol. Sur., Bull.* **620** (1915).

Calkins, F. C., and Butler, B. S., Geology and ore deposits of the Cottonwood-American Fork area, Utah: *U. S. Geol. Sur., Prof. Paper* **201,** 9–10 (1943).

Eardley, A. J., and Hatch, R. A., Proterozoic rocks in Utah: *Geol. Soc. Am., Bull.* **51** 795–844 (1940).

Hinds, N. E. A., Uncompahgran and Beltian deposits of Western North America: *Car. Inst. Wash.*, Pub. **463,** 53–136 (1932).

———, Pre-Cambrian formations in North America: *6th Pacific Sci. Cong. Proc.*, 289–309 (1939).

Hintze, F. F. A., A contribution to the geology of the Wasatch Mountains, Utah: *N. Y. Acad. Sci. Annals,* **23,** 85–143 (1913).

Stansbury, H., Exploration and survey of the valley of the Great Salt Lake of Utah: *U. S. Cong. Spec. Sess. Senate Ex.*, Doc. **3** (1853).

[2] Calkins, F. C., and Butler, B. S., Geology and ore deposits of the Cottonwood-American Fork Area, Utah: *U. S. Geol. Sur., Prof. Paper* **201,** 9–10 (1943).

Cottonwood Canyon, where, according to R. E. Marsell of the University of Utah, it reaches a total thickness of 3000 feet. The rock there seems to be little changed by thermal effects and samples of this unaltered tillite were studied for comparison with the metamorphosed material.

Normal Tillite

Unchanged tillite is generally a hard, dense, blackish to gray, gritty "argillite" which contains scattered pebbles and boulders. The pebbles range in size from $\frac{1}{4}$ inch to boulders several feet in diameter and all are usually rounded to subangular. Rock types represented are quartzite, gneissoid granite, vein quartz, cherty dolomite and marble with the percentages of each varying widely in different areas.

Under the microscope the matrix appears to be composed principally of rounded to very angular fragments (.5–1 mm. diameter) of quartz with subordinate amounts of orthoclase, microcline, and plagioclase. Small lithic fragments of carbonaceous shale, quartzite, limestone or marble, and granite are also found. In between the grains is a dark carbonaceous flour-like material too fine for microscopic identification. A little sericite and chlorite has developed in the matrix evidently due to incipient load metamorphism.

Metamorphosed Tillite

The fresh broken surface of metamorphosed tillite matrix shows a vitreous lustre and a brownish amber color. The rock is extremely hard where the texture is fine and uniform. Pebbles of quartzite and granite appear to be entirely unchanged. No limestone or marble fragments are at all in evidence and their place is apparently taken by greenish patches of a bladed mineral. The patches vary in size from $\frac{1}{4}$ inch to several inches in diameter and present an extreme variety of outline as well as internal structure. Surrounding each green mass is a light colored band varying in thickness up to 5 mm. which grades outward from a light green to nearly white, and then grades into the amber colored matrix. This gives them a zoned appearance which is best observed on a fresh surface but is also quite noticeable on a weathered surface. The central part is often weathered out deeply while the outside zone stands up in a rim. The green blades always develop with random orientation and sometimes show voids between the blades which occasionally are filled with pyrite. The microscope reveals that the dense indeterminate matrix of unmetamorphosed tillite has been recrystallized principally to biotite with interstitial quartz and a black opaque dusty substance which is probably graphite. The dimensions of the biotite flakes are usually in the range of

.05 mm. to .2 mm., though larger flakes are seen in occasional patches.

The fragments of the matrix have undergone little change. Quartz, orthoclase and plagioclase are very clear in appearance and their outline seems to be approximately the same as in the unaltered rock. The green bladed mineral was identified as actinolite with pleochroism in various shades of green and optical properties as follows: $c \wedge Z$ 18°, $\alpha=1.617$, $\beta=1.632$, $\gamma=1.641$; $\gamma-\alpha=.024$, $2V=78°$ and optically (−). The color varies in different specimens from pale green to nearly colorless indicating that the iron content is not constant throughout. The green masses

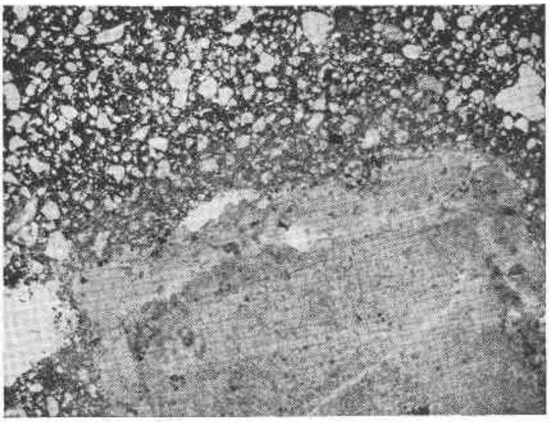

FIG. 1. Photomicrograph of tillite. × 5. Large nearly square actinolite mass in matrix shows small crystals in core (lower right center), border zone of coarse crystals and the outside replacement zone. The matrix is composed of quartz fragments (light) and fine grained biotite with dusty graphite (dark).

as a whole are composed entirely of actinolite, the larger of which show a central fine textured aggregate surrounded by a rim of coarse crystals with a sharp boundry between. (Fig. 1).

Usually outside of the solid actinolite there is a zone up to a maximum width of 5 mm. where actinolite needles replace the matrix and fragments alike (Fig. 1). In this zone also are found a few idioblastic crystals of sphene. Small crystals of actinolite are sometimes found in the matrix mixed with biotite, but these areas are somewhat restricted and can be seen only in thin section.

METAMORPHISM

The metamorphic features described above are found only in the tillite which is near the Cottonwood stock and consequently are presumed to be the result of the rise of temperature consequent to the intrusion.

There are no evidences of introduction of material into the rock, hence all of the new mineral development must be accounted for by reconstitution of the original rock materials.

The biotite, actinolite, and graphite of the groundmass are considered normal developments from a glacial rock flour consisting of fine particles of quartz and limestone or dolomite, clay, carbonaceous and ferruginous materials. It is believed that the solid actinolite masses have developed from the formerly existing limestone and dolomite fragments. An interesting problem connected with diffusion in metamorphism is presented by most of these masses. As previously stated the rim usually has developed large crystals while the center may contain finer grained actinolite, and outside the coarse rim actinolite replaces the matrix in decreasing amount for a distance of about 5 mm. It would be expected that when a rise of temperature takes place the most vigorous development of new crystals would be at or near the boundary of the two substances involved, hence the coarse actinolite on the rims. Slower diffusion would allow silica and iron to penetrate farther into the carbonate masses but smaller crystals would result. Calcium and magnesium oxides have escaped beyond the coarse rim causing the development of the replacing actinolite. According to Harker,[3] diffusion in metamorphism is restricted to a distance of "a small fraction of an inch." Evidences here would confirm this supposition. The presence of sphene in the outer replacement zone only can be explained by the presence here of calcium and titaniferous materials in the original deposit.

[3] Harker, A., Metamorphism, p. 19. Methuen & Co. (1932).

DIFFERENTIAL THERMAL CURVE OF SIDERITE

A. F. Frederickson,
Washington University, St. Louis, Missouri.

While working on the mineralogy of a drill core of bauxite (1) it was found necessary to determine the standard differential thermal curve of siderite. A search of the literature for data on this mineral revealed that only Speil (2) had described the curve. He listed a strong endothermic peak at 590° C. and an exothermic reaction at about 720° C. The siderite curve published by Berkelhamer (3) shows a very strong endothermic reaction. After this reaction the curves goes a considerable distance above the base line but he evidently does not consider this as an exothermic reaction because he makes no mention of it.

Just before the bauxite investigation was completed Cuthbert and Rowland (4) published a new curve for siderite. Using siderite from the