ON NEPHRITE AND JADEITE.*

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(With Plate XXXIII.)

In the ethnological collections of the U. S. National Museum there are many objects of jadeite, nephrite, and of various jade-like stones. They represent a wide range of localities, especially as regards the North American specimens; and in their external characteristics they exhibit great variety in color, texture, and quality. Some came from regions which have already been well studied; but others, as in the series of objects from Alaska and Costa Rica, seemed to merit additional investigation; and at the earnest desire of the late Professor Baird we undertook their mineralogical description. With anthropological questions we have had nothing to do; in each case the nature and character of the material has been our sole study.

In Alaskan specimens the Museum is, as might naturally be expected, particularly rich. Since the acquisition of that Territory by the United States, it has been visited by many official expeditions, and their assembled collections represent the entire coast line from Point Barrow to its southernmost extremity. If we except the remarkable hammers of jade-like pectolite from Point Barrow described by one of us some years ago,† all of the Alaskan jades are true nephrites, indistinguishable in most particulars from the nephrites of Siberia, New Zealand, or the Swiss Lake dwellings. In general terms this nephrite is coarse in quality; but occasionally objects are seen having high finish, some translucency, and great beauty. Of course such objects could not be sacrificed to so destructive an investigation as ours, even though we endeavored to injure specimens as little as possible. In each case in which analysis seemed desirable the necessary material was carefully sawed off, and as little was taken as would suffice for our purposes. The following objects were more or less fully examined by us:

43415. Part of adze, Cape Prince of Wales.
43440. Material for drill, St. Michaels.
44606. Knife-sharpener, Cape Nome.
44920. Knife-sharpener, Sledge Island.
44921. Knife-sharpener, Sledge Island.
44922. Knife-sharpener, Sledge Island.
63715. Stone implement, Diomede Island.
63733. Small knife, Diomede Island.
63762. Sharpening tool, Hotham Inlet.
89622. Knife-sharpener, Point Barrow.
89658. Stone adze, Point Barrow.

* In this investigation the chemical work is entirely due to F. W. Clarke, and the microscopic work to G. P. Merrill.

† Clarke, Amer. Jour. Sci., 1884.

Of these the last two were collected by the Signal Service expedition commanded by Lieut. P. H. Ray; the others were received from Mr. E. W. Nelson. For each specimen the specific gravity was carefully determined by Dr. William Hallock, of the U. S. Geological Survey. The general description of the material may be summarized thus:

43415. Yellowish-green, mottled, sp. gr. 2.989.
43440. Siskin-green, translucent, uniform sp. gr. 3.006.
44606. Olive-green, sp. gr. 2.988.
44920. Olive-green, mottled, sp. gr. 2.928.
44921. Olive-green, mottled, darker, sp. gr. 2.921.
44922. Superficially black, sp. gr. 2.963.
63715. Siskin-green, translucent, sp. gr. 3.002.
63733. Blackish green, mottled and laminated, sp. gr. 3.010.
63762. Olive-green, mottled and laminated, sp. gr. 2.975,
89622. Olive-green, translucent, sp. gr. 2.978.
89658. Nearly black superficially, sp. gr. 2.922.

Of these, Nos. 43415, 43440, 63733, and 89658 were selected for analysis and microscopic study. The following table gives the results of the analyses:

	43415	43440	63733	89658
Ignition	1.91	1.42	2.03	2.06
Silica	56.01	56.12	56.08	57.11
Alumina	1.98	.63	1.01	2.57
Ferrous oxide	6.34	7.45	7.67	5.15
Maganous oxide	trace.	trace.	trace.	trace.
Lime	12.54	12.72	13.35	11.54
Magnesia	21.54	20.92	19.96	21.38
	100.35	99.26	100.10	99.81

In each case the ferrous oxide represents the total iron. Ferric oxide was not discriminated, nor were alkalies looked for. So far, then, the analyses are imperfect.

In addition to the above-named implements, another object of supposed jade was investigated. It was a flaker (No. 89624) from Point Barrow, of dull bluish green color, conchoidal fracture, considerable translucency, and specific gravity 2.654. These data, together with a partial analysis, identify the specimen as quartz. It contained 97.79 per cent. of silica.

Before going on with the discussion of the microscopic character of the jades another series of specimens remains to be noticed. As regards origin, some early writers have attributed the Alaskan nephrite to Siberian sources, but of late years it has been generally ascribed to a home locality. Native reports pointed to a source known as the Jade Mountains, north of the Kowak River, about 150 miles above its mouth; and after several attempts the spot has been actually visited by Lieut. G. M. Stoney. He collected specimens of jade *in situ*, and a number of samples were submitted to us for examination. They may be described as follows:

A. Greenish gray, splintery, lamellar in structure,

B. Like A, but more granular.

C. Paler, nearly white, closer grained.

D. Brownish, highly foliated.

All four were analyzed with the subjoined results:

	A.	B.	C.	D.
Ignition	1.78	1.38	1.76	1.73
Silica	58.11	55.87	56.85	57.38
Alumina	.24	2.07	.88	.19
Ferric oxide	5.44	5.79	4.33	4.43
Ferrous oxide	.38	.38	1.45	1.25
Manganous oxide	trace.	trace.	trace.	trace.
Lime	12.01	12.43	13.09	12.14
Magnesia	21.97	21.62	21.56	22.71
	99.93	99.54	99.92	99.83

Studied in thin sections, under the microscope, the Alaskan nephrites present the following characteristics:

A. This sample, as seen in the slide and by ordinary light, presents a uniformly colorless field of a homogeneous, non-pleochroic mineral, and is transversed by fine wavy rifts running all in the same general direction. The inclosures are very minute, some are mere dust-like particles, others are distinctly recognizable as limonite. Between crossed nicols the entire field is covered with very indefinitely outlined areas, which are alternately light and dark as the stage is revolved. With a power of two hundred and thirty diameters these areas are seen to be composed of wavy and uneven scales and bundles of fibers so interwoven and confused that no trustworthy measurements of extinction angles are obtainable. Many of the bundles seem to extinguish in directions approximately parallel with their length; but others show wide angles. The worked jade, 43415, from Cape Prince of Wales, has essentially the same structure as A, and needs no separate description. No. 43440, from St. Michaels, is also quite similar. In this specimen the fibers are short and scale-like. There are no inclosures of note, although there is a plentiful sprinkling of amorphous dust-like material. No. 63733, from Diomede Island, is also much like A. It presents no difference which can be considered mineralogically essential, but the texture is more uneven, and many of the fibrous tuft-like masses are larger. The variations, however, are no greater than might occur in samples from the same mass.

B. This specimen in thin sections and by ordinary light is also almost colorless, or very faintly greenish, and without pleochroism. It shows only a few yellowish and opaque inclusions, which are evidently of a ferruginous nature. Between crossed nicols it exhibits the well-known nephritic structure—a dense aggregate of short fibers and scales, the fibers arranged in clusters, or radiating tuft-like bundles, without definite boundaries, which merge into one another as the stage is revolved. In cases where the bundles are composed of fibers lying approximately parallel, angles of extinction were measured varying from 0° to 15°. The structure may be best understood by reference to fig. 2. It corresponds quite closely with a nephrite from the Belaja River, in Siberia, as described and figured by Beck and Muschketow,* but it is more uniform in texture, and resembles more nearly the jade from New Zealand. (See also figs. 1 and 3.) The Point Barrow specimen, 89658, has the same structure as B, and needs no further description.

The foregoing evidence is sufficient to show the essential identity of all the Alaskan jades, and to dispose of the theory that their presence in Alaska is to be accounted for upon the basis of trade with Siberia. That theory is also negatived by the discovery, announced by Mr. G. M. Dawson,† of small nephrite bowlders on the upper part of the Lewes River, not far from the eastern boundary of Alaska. But these nephrites are also strikingly like those from many other localities, and two of the latter have been included in our comparisons. First, a water-worn, dark-green bowlder from New Zealand, sent to the Museum by Sir Julius Haast; and second, a small implement from Robenhausen, Lake Pfäffikon, Switzerland, out of the collection of Mr. Thomas Wilson. The latter specimen, also green, had a specific gravity of 3.015, as determined by Dr. Hallock. The analyses are as follows:

	New Zealand.	Swiss.
Ignition	.83	.63
Silica	56.73	56.87
Alumina	3.22	1.50
Ferrous oxide	5.96	6.33
Lime	13.24	13.45
Magnesia	19.42	21.06
	99.40	99.84

All the iron is represented here as ferrous. Traces of manganese were present, but alkalies were not looked for.

In thin section, under the microscope, the Robenhausen jade is seen to be made up of an extremely fine and compact aggregate of fibers, scales, and tufts, all arranged with their longer axes approximately parallel, so as to produce a more or less schistose structure. Sections cut parallel to this schistosity exhibit, in ordinary light, colorless, elongated, narrow areas, bounded by very irregular wavy lines which a high power shows to be rifts stained by impurities. Between crossed nicols the entire field is converted into a confused mass of brilliantly polarizing fibers, from which no measurement of extinction or cleavage angles are obtainable. Cross sections show a peculiar felt-like groundmass of colorless particles, polarizing only in light and dark colors, and blending into one another without definite lines of demarkation when the stage is revolved. The field shows numerous larger elongated areas,

* Ueber Nephrit und seine Lagerstatten, p. 12, Fig. 1.
† Science, April 20, 1888, p. 186.

lying with their longer axes parallel, which give extinctions nearly, if not quite, parallel with those axes. Except so far as to show the homogeneity of the mineral, the optical examination is quite unsatisfactory.

The New Zealand jade, as seen under the microscope, consists wholly of a very compact aggregate or felt-like mass of confused scales and minute fibers, arranged in bundles and tufts in a manner which can be best understood by a reference to fig. 1. The dark interstitial portions there shown are, when the stage is revolved and the nicols are crossed, seen to be composed of fibers and tufts of the same character as the lighter parts. In ordinary light these are almost perfectly colorless, and not perceptibly pleochroic. Between crossed nicols they show brilliant polarization in yellow, red, and purple colors. The fibrous, bent and tufted form of the mineral renders a determination of its optical properties difficult, and in many cases impossible. In the few instances that they are gathered into long bundles in which the fibers are lain approximately parallel, they are found to give extinction angles varying from 0° to 20°, indicative of a mineral of the amphibole group—an indication fully borne out by the analysis. The only inclosures are minute, dust-like particles of a black or yellow color, evidently ferruginous, but which a power as high as 750 diameters fails to satisfactorily determine. This structure is identical with that shown by slides in the museum collection made from jade implements from New Zealand. Jade from the same locality has also been studied by Arzruni,* who describes it as an extraordinarily dense mass of bent and contorted fibers, stained yellowish in spots by iron oxide, and without inclosures. Our analysis agrees sufficiently well with that of Mr. C. L. Allen† of a jade from the same locality, to insure identity of material.

The same structure, with slight modifications, is common to the nephrites of New Caledonia and Siberia, as shown by sections of them in the Museum collection. Indeed, this finely fibrous and tufted structure appears to be characteristic of true nephrite, from whatever locality. Thus, Arzruni‡ describes a nephrite from southeastern Alaska as possessing a microscopic structure uniformly fine and fibrous throughout. The fibers, though but little bent and curved, seldom lie parallel with one another, but are grouped into loose, irregularly-outlined, and tufted bunches. In the less compact portions the fibers intersect each other at approximately right angles, forming a grate-like, reticulated structure. This he regards as a commencement of alteration into what may be serpentine or bastite. Such an alteration is accompanied by a slight browning of color, due to the liberation of iron oxide. He regards the isolated fibers as a variety of amphibole, and compares the general structure with that of a nephrite from the Kitoj River, Irkutsk, Siberia, which has been described by Beck and Muschketow, and which will be noted later. He states, however, that it differs from the Siberian

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* Zeit. für. Ethnologié, 1883, p. 183.

† Chem. News, 1882, p. 216.

‡ Jahresbericht des Vereins f. Erdkunde zu Dresden, 1885, p. 6.

nephrite in that the latter has its fibers finer and grouped in long bunches, or in spreading tufts, as shown in our fig. 3. Such, however, may be mere local variations; and a more weighty distinction is based upon the presence of inclosures of foreign matter in the Siberian nephrite which are quite lacking in the specimens from Alaska. The analysis given by Dr. Meyer in this paper, although differing somewhat from that of our series, is sufficient to insure identity of material.

Beck and Muschketow* describe the Kitoj River nephrite as dark leek-green in color and of a lamellar structure.

Sections cut parallel and at right angles with the lamination show in the one case a prevailing confused fibrous and parall l fibrous ("verworren-faseriges u. parallel-faseriges") structure, and in the other a microgranular and lamellar structure. Under a power of ninety-five diameters and in ordinary light the section is traversed by clear colored veins, which stand out boldly from the surface when the nicols are crossed. These are bordered by extremely fine fibers arranged both parallel and at right angles with the veins, and show by their aggregate polarization and optical behavior that they are asbestus. This structure is shown only in sections cut parallel with the lamination. The Belaja River nephrite is described by the same author as showing under the microscope a confused fibrous aggregate of extremely fine needles of various sizes, the larger some 0.0043^{mm} in thickness, and, with a length many times greater, rarely a thickness of 0.04^{mm} is attained. The fibers are extraordinarily confused and without the slightest regularity in their arrangement, though in some cases an approximately parallel arrangement occurs which gives rise to a pseudo-microfluidal structure. More commonly the fibers are found in tufts, radiating from a common point, "*Strahlenartig*." In consequence of the homogeneity of the aggregate it is assumed that the fibers belong all to the same mineral species. Inclusions are abundant. Limonite is the most common, occurring as small black points, and often staining the adjacent needles a brown color. This coloring matter sometimes segregates into veins of sufficient size to be apparent to the unaided eye. Other dark inclosures are believed to be chromite. As in the last case, sections at right angles to the lamination show a less pronounced fibrous structure, but are rather microgranular. Still another nephrite from the Bustraja River has the fibers so extremely small that a great number could be seen (when magnified five hundred diameters) grouped in a space 0.0043^{mm} in breadth. These asbestus-like fibers are regarded as secondary, as are also small colorless sections with which they are sometimes associated, and which from their optical behavior are supposed to be serpentine. A nephrite from the Caucasus has similar properties. One from the Jarkand Valley in Turkestan differs from the last in carrying a considerable number of magnetite inclosures which are visible to the naked eye. Its microstructure greatly resembles that

*U. Nephrit u. seine Lagerstätten. Verhand. der Kaiserlichen Min. Gesell. zu St. Petersburg: II series, XVIII.

of the Siberian nephrites, but presents certain peculiarities. The groundmass has a like microgranular and fibrous structure, but sections cut at varying angles with the apparent schistosity show no such separation between the granular and fibrous parts as was observed in the Siberian stone. These structures are shown in figs. 3 and 4, Pl. I, of their paper. They think to distinguish between the Jarkand and Siberian nephrites by their inclosures of foreign particles. In all Siberian nephrites the iron occurs in the form of limonite or chromite, while in those of Jarkand it occurs wholly as magnetite and hematite. These differences are shown by analysis. Another marked difference lies in the irregular massive aggregates sometimes occurring in sizes up to 0.05^{mm}. These from their optical and cleavage properties are judged to be diopside. A nephrite from Samarkand showed inclosures of a similar nature.

The distinction given in the résumé by these authorities, between the Siberian and Turkestan nephrites, are that the first named show a clear microschistose structure with inclosed grains of chromite and limonite; while the last named is massive, with very few inclosures of ferruginous granules, but in place of these characteristic inclusions of diopside or a closely related mineral. A nephrite from Pekin was found to possess all the microscopic properties of that from Jarkand. The microscopic examinations of Messrs Beck and Muschketow were in all cases accompanied by chemical analyses, and the paper as a whole forms a most important addition to the literature of the subject.

Mr. Otto Schœtensack,* in a paper on the subject, describes a nephrite from the Tienshan Mountains of a dark green color and specific gravity of 2.98, which shows between crossed nicols a fine crystalline texture, with many included asbestus-like fibers, giving extinction angles varying from 12° to 16°. Rarely are seen concentric aggregates of fine bent fibers. Strongly dichroic, yellowish brown and yellowish green granules are supposed to be epidote. Another nephrite from Khoten in Bokhara, with a specific gravity of 2.947 and of a violet-gray color, shows between crossed nicols a confused, short fibrous texture, with the fibers but slightly bent, through which are distributed large crystalline areas in which the fibers are much more contracted. This is apparently the same structure as shown in some Siberian nephrites by Beck and Muschketow.

Of jade objects from Mexico the National Museum has a large and fine series, but nearly all the specimens are from the one State of Oaxaca. The greater number of them consist of true jadeite; but as jadeite from the same region has been described by Damour,† a very exhaustive review of the material did not seem to be necessary. A good series of specific gravity determinations was, however, made by Dr. Hallock, and

*Die Nephritoide des mineralogischen u. d. ethnographisch-prähistorischen Museums der Universität Freiburg im Breislau. Inaug. Dis. Berlin, 1885.

†Bull Soc. Min., IV, 157.

two specimens were also submitted to chemical and microscopic study. The following objects were examined:

1. Bead of light color, mottled with emerald green. Blake collection, No. 127. Weight 12.81 grammes, specific gravity 3.007.

2. Head, light green, from Zaachila. Aymé collection, Museum number, 115213. Weight 21.517 grammes, specific gravity 3.190.

3. Dark, dull green, translucent amulet. Blake collection, No. 79. Weight 131,695 grammes, specific gravity 3.332.

4. Human figure, light greenish, finely polished. Blake collection, No. 35. Weight 68.409 grammes, specific gravity 3.152.

5. Head and bust, dull opaque green. Blake collection, No. 77. Weight 186.627 grammes, specific gravity 3.338.

6. Face with head gear and pendants, light emerald green, grayish back. Blake collection, No. 38. Weight 30.274 grammes, specific gravity 3.232.

7. Head with grotesque mask, dark opaque green. Blake collection, No. 36. Weight 47.432 grammes, specific gravity 3.087.

8. Serpent head, translucent, mottled green. Blake collection, No. 37. Weight 39.09 grammes, specific gravity 3.337.

9. Ring, pale opaque green, near No. 4. Blake collection, No. 25*a*. Weight 791 grammes, specific gravity 3.199.

10. Celt-like object, blackish green, from Cholulu. Blake collection, No. 54*d*. Weight 293.91 grammes, specific gravity 3.355.

11. Rude, squarish head, light green. Scratched by steel. No number nor locality. Weight 70.54 grammes, specific gravity 2.758.

12. Light green jadeite amulet, highly polished. Aymé collection, No. 105. Weight 100.365 grammes, specific gravity 3.337.

13. Whitish, mottled human figure, dull polish, opaque. From San Martin Mexicampas. Aymé collection, No. 401. Museum number, 115236. Weight 103.78 grammes, specific gravity 3.021.

The specific gravity of several other Mexican jadeites in the Museum collection was determined several years ago by the late G. W. Hawes. As the data are unpublished they may fairly be inserted here:

Mus. No. 7844. Polished grayish green hatchet. Granular texture, specific gravity 3.34.

Mus. No. 7845. Polished ornament from Mirador. Grayish green, less granular, specific gravity 3.34.

Mus. No. 27874. Three beads. Mottled green and gray, coarsely granular, specific gravities 3.11, 2.94, 2.93.

Of these objects all but No. 11 appear to be jadeite. No nephrite could be identified among them. Nos. 1 and 2 were selected for further study, and gave the following analyses:

	1	2
Ignition	1.81	.53
Silica	58.88	58.18
Alumina	25.93	23.53
Chromic oxide	.12	....
Ferrous oxide	.24	1.67
Lime	.40	2.35
Magnesia	.36	1.72
Soda	11.64	11.81
Potassa	.63	.77
	100.01	100.56

If the water in No. 1 be regarded as replacing alkalies, the mineral approximates very nearly in composition to normal jadeite, $AlNa(SiO_3)_2$. Both analyses fit in well with Damour's series.

Under the microscope No. 1 resembles No 59927 from Costa Rica, to be described further on. It is a granular aggregate of colorless or greenish crystals at very imperfect outline, none pleochroic, but polar. izing in very brilliant colors. It has, however, a much coarser texture than the Costa Rica specimen; the larger granules measuring at times 2 millimeters in diameter. These larger forms are all monoclinic with the optic axis in the plane of symmetry, and give extinction angles on sections parallel with the clinopinacoid varying from 35° to 40°. Promnent prismatic cleavages are developed, which in basal sections cross at nearly right angles. Many of the crystals also show twin lamellæ and carry numerous fluidal inclusions with rapidly moving bubbles.

The striking feature of the section is that the granules are all badly shattered and traversed by irregular fractures, which, with a power of seventy-five diameters, appear somewhat like the irregular canals of serpentinous matter so often seen in altered olivine. Under a power of one hundred and seventy diameters it becomes apparent that they are undergoing alteration into a fibrous nearly colorless product resembling the common change of augite into fibrous hornblende as seen in basic rocks. The alteration begins with a fraying out along the lines of cleavage and fracture, and has in a few instances gone on till but a rounded granule remains of the original mineral.

In many instances these veins of fibrous material carry plates of a clear, colorless, biaxial, eminently micaceous mineral, showing between crossed nicols the peculiar blistered appearance and brilliant iridescent polarization colors of muscovite. From their small size I am unable to say whether they are in all cases a product of alteration of the pyroxene or original inclosure. I am, however, inclined to the former hypothesis, since they occur only along lines where the alteration is greatest and have not been observed in the perfectly unaltered mineral. In some of the larger jadeite objects of the Museum collection from this same locality the micaceous mineral appears in flakes of such size as to be macroscopically recognizable in the form of minute silvery white inelastic scales. The chemical composition of the rock as a whole is such as to indicate that they are paragonite rather than muscovite. Where these veins are widest the interior is often occupied by a clear and perfectly colorless biaxial mineral without cleavage or crystalline outline, which polarizes in brownish or yellow colors, and which shows the same optical orientation over considerable areas, thus giving rise to what may be called a pseudo-ophitic structure, the grains of still unatered pyroxene representing the inclosures. Fig. 4 shows the structure of this rock as it appears under a power of twenty-five diameters.

The second jade, No. 115213, is, like the last, an aggregate of imperfectly outlined crystals. Under the microscope the texture is found to be very uneven; portions of the slide showing aggregates of extremely small and ill-defined particles which permit of no satisfactory measurements or determinations, sometimes slightly fibrous or scale-like, and sometimes granular, while other portions show distinct crystalline forms of all sizes up to 1 millimeter in diameter and which show the cleavage and optical properties of a monoclinic pyroxene. The clear, colorless, mica-like mineral also occurs here. The rock otherwise differs in no essential particular from a jadeite from China, samples of which we have here, received from Dr. A. D. Meyer (28820).

With Central American jade objects the Museum is well supplied. A few only are from Nicaragua and Guatemala; the finest are all Costa Rican. Here, too, jadeite is the dominating mineral species; although with the true jades are many articles of softer green stones, and occasionally an object of quartz or chalcedony. To Dr. Hallock's series of specific gravity determinations we may properly add a number of earlier values obtained several years ago by the late G. W. Hawes and by Mr. F. W. Taylor, and not hitherto published. The specimens examined are described below, following the order of their density:

No. 59931. Polished ornament, Sardinal, Costa Rica. Deep olive-green, not distinctly granular, specific gravity 3.344, Hallock.

No. 59908. Polished ornament, Sardinal. Pale green with whitish flecks, translucent, slightly granular, specific gravity 3.332, Hallock.

No. 28977. Elaborate carving, Nicoya, Costa Rica. Dark, rich green, translucent, granular, specific gravity 3.33, Hawes.

No. 31906. Polished tube, Guatemala. Light, grayish green, granular, specific gravity 3.33, Hawes.

No. 28990. Fragment, Sardinal. Light green, very granular, specific gravity 3.33, Hawes.

No. 59907. Ornament, Sardinal. Mineral like No. 28977, specific gravity 3.326, Hallock.

No. 59947. Ornament, Jesus Maria, Costa Rica. Blackish green, mottled, granular, specific gravity 3.32, Taylor.

No. 59927. Fragment, Sardinal. Pale green, translucent, specific gravity 3.32, Clarke.

No. 28992. Fragment, Culebra, Costa Rica. Mineral, like No. 28990, slightly darker, specific gravity 3.27, Clarke.

No. 28991. Hatchet, Liberia, Costa Rica. Grayish green, finely granular, specific gravity, 3.26, Hawes.

No. 10452. Large ornament, Ometepec Island, Lake Nicaragua. Varying shades of green and grayish green, very finely granular, specific gravity 3.26, Hawes.

No. 59968. Small ornament, Nicoya. Dark green, not distinctly granular, specific gravity 3.11, Taylor.

No. 59917. Small ornament, Sardinal. Bright green, granular, specific gravity 3.01, Taylor.

No. 59857. Small ornament, Las Huacas, Costa Rica. Green and gray blotches, coarsely granular, specific gravity 2.956, Hallock.

No. 28987. Ornament, Liberia. Greenish gray, granular, specific gravity 2.87, Hawes.

No. 60048. Fragment, Rio de Buena Vista, Costa Rica. Green, translucent, specific gravity 2.71, Clarke.

No. 59923. Ornament, Sardinal. Pale olive-green, compact, not granular, specific gravity 2.65, Taylor.

No. 59856. Ornament, Las Huacas. Bluish green, mottled, not granular, specific gravity 2.621, Hallock.

No. 59845. Ornament, Nicoya. Like 59857, but darker, specific gravity 2.62, Taylor.

No. 59932. Ornament, Sardinal. Grayish green, faintly translucent, not distinctly granular, specific gravity 2.62, Taylor.

No. 59937. Ornament, Panama, Costa Rica. Like 59932, specific gravity 2.62, Taylor.

No. 59955. Ornament, Boquerones, Costa Rica. Like 59932 and 59937, specific gravity 2.60, Taylor.

No. 328. Ornament, Ometepec Island, Lake Nicaragua. Brownish, highly polished, specific gravity 2.593, Hallock.

No. 59855. Ornament, Las Huacas. Like 59856, specific gravity 2.589, Hallock.

No. 59860. Ornament, Las Huacas. Dull bluish-green, opaque, specific gravity 2.377, Hallock.

No. 59858. Ornament, Las Huacas. Dull light-green, soft, specific gravity 2.324, Hallock.

No. 59912. Ornament, Sardinal. Like 59858, specific gravity 2.30, Taylor.

No. 59894. Ornament, Sardinal. Dull grayish green, soft, specific gravity, 2.294, Hallock.

No. 59868. Small ornament, Nicoya. Dark green, specific gravity 2.29, Taylor.

No. 59899. Ornament, Las Huacas. Dark green, not mottled, soft, specific gravity 2.282, Hallock.

No. 59924. Ornament, Sardinal, dull green, not mottled, soft, specific gravity 2.266, Hallock.

It will at once be seen that these objects, as regards density, fall into three pretty well defined groups. The highest values represent jadeite, more or less impure, and of various qualities; the middle group is near quartz in specific gravity, and some of its members certainly belong to that species; the lowest division contains ill-defined substances, which are also characterized by softness.

Four of the objects, viz, two jadeites, one quartz-like mineral, and one of the softer stones were selected for more complete investigation. The supposed quartz, No. 60048, from Rio de Buena Vista contained 97.10 per cent. of silica, 1.85 per cent of alumina and oxide of iron, no lime, and no magnesia. No further examination seemed to be necessary. The jadeites, Nos. 59927 and 28992, however, were more interesting. In composition they are as follows:

	59927, Sardinal.	28992, Culebra.
Ignition	.90	.93
Silica	59.18	58.33
Alumina	22.96	21.63
Ferric oxide	1.87 (Ferric and ferrous oxide together)	1.71
Ferrous oxide		.73
Lime	1.52	4.92
Magnesia	.67	3.09
Soda	12.71	8.13
Potassa	trace.	.22
	99.81	99.69

Traces of manganese were found in both samples.

Of these jades, the first was fine in color, texture, and translucency; the second was coarse, mottled, and opaque. The one approximates in composition to normal jadeite, the other varies from it both in composition and density.

Under the microscope the Sardinal specimen appears as a finely granular aggregate of colorless crystals, none of which possess perfect crystalline outlines, because of mutual interference. The texture is very uneven, scattering and clustered forms, from 0.1 to 0.5^{mm} in diameter, being distributed irregularly through a ground-mass composed of minute granules and scales which between crossed nicols blend into each other without distinct lines of separation. The mineral is almost perfectly colorless in the thin section or with a very faint greenish tinge and non-pleochroic, but polarizes in brilliant red, yellow, and purple colors. It is rendered slightly impure through inclosures of innumerable minute black and brownish dust-like particles the nature of which a power of seven hundred and fifty diameters fails satisfactorily to determine.

The larger forms show two well-developed cleavages which in basal sections cut each other at approximately right angles. An optic axis lying in the plane of symmetry appears in both basal and orthopinacoidal sections. The angle of extinction for section parallel to $\infty P \infty = 0^\circ$; and for those parallel to $\infty P \grave{\infty}$ varies from 35° 40°. These are properties common to the monoclinic pyroxenes, and would not in themselves alone indicate decisively any one particular variety.

Krenner,* who has studied jadeites of similar composition and structure from Burmah, claims as a result of his examinations and the analyses of Damour, that the mineral is a soda-spodumene.

The Culebra jadeite, 28992, differs structurally from the last (59927) in that it is made up largely of an aggregate of elongated and irregular scales and fibers compactly matted together, in which the individual scales blend into one another as the stage is revolved. It seems to correspond to the "*Stengel-faserig*" aggregate of the Germans. Throughout this scaly fibrous ground-mass are scattered occasionally larger and very irregular forms wholly without crystal outlines and rarely showing cleavage lines. All are colorless and non-pleochroic, and both large and small give extinction angles varying from 29° to 40°.

The descriptions given above agree closely with those of other observers. M. Cohen† describes a jadeite from Thibet as a granular aggregate of crystals of a mineral belonging to the pyroxene group and of *omphaeite-like* habitus. The crystals show a nearly rectangular cleavage, give extinction angles of 41°, and show an optic axis in both orthodiagonal and basal sections. Fluidal inclusions were observed and occasional

* Neues Jahrb., etc., 1883, II, 1st H., p. 173.

† N. Jahr. f. Min., etc., 1884, 1 B., 1 Heft., p. 71.

grains of free quartz. Schoetensack* describes a "true jadeite" from Monghoung, in Burmah, as being a homogeneous aggregate of large granules and long curved lamellæ, with the cleavage of pyroxene (87°), and giving extinction angles of 35°.

The last of the four Costa Rican specimens examined was the soft dark green specimen from Las Huacas, No. 59899. In composition it is as follows:

Ignition	10.39
Silica	70.49
Alumina	11.39
Ferrous oxide	2.39
Manganous oxide	trace
Lime	3.83
Magnesia	.57
Alkalies	undetermined
	99.06

A microscopic examination shows that the mineral is evidently a highly altered volcanic tuff, but very difficult to make out. The mass of the rock is made up of a greenish-gray amorphous felt, through which are scattered rounded bunches of a bright green chlorite and small, colorless points and elongated crystals, which may be felspathic, although they are too small to show twin striæ. There are also occasional colorless, elongated, and curved shreds, which are wholly without action in polarized light and which are doubtless glass.

Two portions of a chambered shell of a minute rhizopod occur in the slide. Not even by courtesy can this substance be classified as jade.

Through the kindness of Mr. Thomas Wilson, whose collection furnished the Robenhausen nephrite already described, we have been enabled to examine several other worked specimens of minerals which are sometimes classed, though loosely, with jade. They come from various localities and may be briefly summarized as follows, in the order of their specific gravity as determined by Dr. Hallock:

No. 100365. Robenhausen, Lake Pfäffikon, Switzerland. Green, mottled saussurite, specific gravity 3.418.

No. 100586*a*. Same locality. Dark green saussurite, specific gravity 3.403.

No. 100031. From Brittany. Chloromelite? Dark green, mottled, specific gravity 3.392.

No. 100630. Yverdun, L. Neuchatel, Switzerland. Pale green adze, specific gravity 3.347.

No. 100238. Brittany. Fibrolite, specific gravity 3.147.

No. 100516. Estavayer, L. Neuchatel. Black, specific gravity 3.132.

No. 100629. Yverdun. Green nephrite, specific gravity 3.028.

No. 100586*b*. The Robenhausen nephrite already described, specific gravity 3.015.

No. 100670. L. Constance. Dark green nephrite, specific gravity 3.009.

No. 100029. Brittany. Black mineral, specific gravity 2.705.

Of these the fibrolite, 100238; the saussurite, 100586*a*; and the

* *Op. cit.*, p. 7.

black specimen, 100516, were examined further, and an analysis was also made of a fragment of massive saussurite from the Saas Valley, Switzerland, out of the Museum collection. The results of analysis were as follows:

	Fibrolite, 100238.	From Estavayer, 100516.	Saussurite, 100586*a*.	Saussurite, massive.
Ignition	1.31	.65	.30	.54
Silica	34.66	45.13	49.90	48.29
Alumina	63.24	16.55	29.76	27.65
Ferric oxide	trace	13.59	2.52	1.45
Ferrous oxide	....	4.20		
Manganous oxide	....	trace	....	....
Lime	none	11.02	11.77	12.95
Magnesia	.37	5.48	5.80	5.36
Soda	....	3.89	3.21	3.57
Potassa	....	trace	trace	trace
	99.58	100.51	100.26	99.81

Chemically the second of these rocks is like a saussurite, saussurite itself being a very variable mixture, ranging from mainly a zoisite to mainly a feldspar. Microscopically, however, it is seen to be a mixture of various minerals, and is evidently a highly altered basic rock, possibly a diorite. If so, the original constituents are now so completely altered as to be scarcely recognizable. The most abundant constituent is a bright green or bluish amphibolic mineral, mixed with more or less chloritic matter and various decomposition products. Throughout this ground-mass are scattered abundant yellowish grains and granular aggregates of secondary epidote, a colorless mineral with the optical properties of zoisite, and rounded grains of an iron ore, each inclosed in a narrow, nearly colorless border of leucoxene (?). The felspars, if such existed, are no longer recognizable. Other minerals of a secondary nature are present, but need not be alluded to here.

As for the fibrolite, No. 100238, this is shown by the microscope to be made up of innumerable minute, greatly elongated, colorless needles arranged in bundles with their longer axes approximately parallel, often broken transversely, and crowded into a dense mass, and usually with a decided plumose structure. The needles are to minute for a determination of their optical properties. These needles make up the entire mass of the rock, except for a few minute rounded granules, which are quite opaque and resemble an iron ore.

The question has been asked if there are any means by which an object may be identified as nephrite or jadeite without resorting to the destructive process of cutting a thin section or making other tests such as will involve a more or less defacement of the object. In a general way it may be stated that the jadeites are of a distinctly granular, or at least scaly-fibrous texture, while the nephrites are uniformly fibrous and compact throughout. These distinctions can sometimes be detected by the eye alone or with the pocket lens, as in the case of the jadeite beads from Mexico. Professor Arzruni,* however, has shown that nephrite is not in all cases an original mineral, but in some instances results from a molecular re-arrangement or uralitization of a mineral of the pyroxene group. He, therefore, very appropriately divides them into the primary nephrites and pyroxene nephrites. H. Traube† has shown, too, that a portion of the nephrite from Jordansmühl in Silesia is secondary; as is also that of Reichenstein, the latter resulting from the molecular alteration of diopside.‡

Beck and Muschketow § too, it will be remembered, considered the asbestus fibers in the Bustraja nephrite as secondary, and noted the presence of still unaltered granules of diopside in the nephrite from Samarkand and Turkestan. It would therefore appear that the true nephrite may grade into a granular diopside rock resembling jadeite, and that therefore the purely macroscopic method suggested can not in all cases be relied upon implicitly. A safer, and indeed the only practical, means of distinguishing between the two substances under the circumstances noted above would seem to be by their specific gravities, the jadeites varying from 3.01 to 3.32, while the nephrites rarely reach a density of 3.00.

As regards the possibility of distinguishing by means of thin sections and the microscope between nephrites from various sources. A majority of the authorities consulted (and among them are those who have devoted much time to the subject and who having critically examined a large number of slides are capable of rendering opinions of value) appear to favor the view that this is practicable. As for ourselves, with our present experience, we confess to a feeling of skepticism. The presence or absence of inclosures of diopside, magnetite, or ferruginous oxides, the condition of these oxides, whether as ferric or ferrous, the varying tufted, bent, confused fibrous and even granular condition of the constituent parts, are all, together with the color variations and other structural peculiarities, matters of two slight import to be of weight from a petrographic stand-point. If, as seems possible, the majority of the nephrites are of secondary origin, why may we not expect to find all, or at least a great variety, of the structures described in the same or closely adjacent rock masses? Chemical analyses on samples from near-lying, or even the same, localities are found often to vary as greatly as those from localities widely separated. Why may we not expect the same structural variations when once they are carefully looked for? To our own minds sufficient assurances that the widely scattered jadeite and nephrite objects were derived from many independent sources and pos-

* Zeit. für Ethnologie, 1884, p. 300.

† Neues Jahrb. f. Minn., etc. Beilage Band III. 2. Heft, 1884, p. 417.

‡ Neues Jahrb. f. Minn., 1887, II B., 2 Heft, p. 275. The alteration is accompanied with a diminution in the amount of lime; the diopside yielding 21.41 per cent. and the tremolite (nephrite) 11.16 per cent.

§ *Op. Cit.*

sess no value whatever in the work of tracing the migration and intercommunication of races lies in the fact that these substances are comparatively common constituents of metamorphic rocks and hence liable to be found anywhere where these rocks occur. Their presence is as meaningless as would be the finding of a piece of graphite. The natives required a hard, tough substance capable of receiving and retaining a sharp edge and polish, and took it wherever it was to be found.

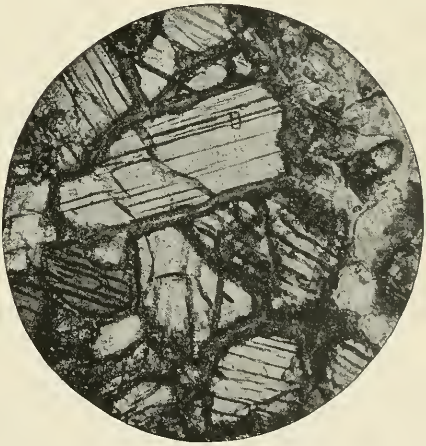
EXPLANATION OF PLATE—MICROSTRUCTURE OF NEPHRITE AND JADEITE.

Fig. 1. Nephrite, New Zealand .... $\frac{25}{1}$
2. Nephrite, Alaska .... $\frac{25}{1}$
3. Nephrite, Liberia .... $\frac{25}{1}$
4. Jadeite, Oaxaca, Mexico .... $\frac{25}{1}$

1.

2.

3.



4.

MICROSTRUCTURE OF NEPHRITE AND JADEITE. (Page 115.)

FIG. 1. Nephrite, New Zealand. $\frac{25}{1}$.
FIG. 2. Nephrite, Alaska. $\frac{25}{1}$.
FIG. 3. Nephrite, Siberia. $\frac{25}{1}$.
FIG. 4. Jadeite, Oaxaca, Mexico. $\frac{25}{1}$.