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On the occurrence of turquoise in Cornwall.

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With a chemical analysis by E. A. Vincent, Ph.D., A.R.I.C., F.G.S.

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In my description of the mineral rashleighite, which was given in this magazine in 1948,[1] I mentioned that most of the mineral from the Bunny mine, St. Austell, was in colour light blue-green, but that it was also sometimes true turquoise-blue. Likewise, at the Castle-an-Dinas wolfram mine, St. Columb Major, there occurred rarely in addition to the blue-green rashleighite a true turquoise-blue mineral which was first assumed to be turquoise[2] and later rashleighite. It has now been found, however, that this turquoise-blue mineral is in fact true turquoise, and distinct from the green rashleighite.[2] Specimens of this turquoise were found at the Bunny mine, associated with varlamoffite.[3]

I have since found much larger and better specimens at the Gunheath china-clay pit, St. Austell (six-inch ordnance map, Cornwall, 41 SE., 1908), which lies some 670 yards south-west of Bunny mine. Traversing almost the full length of the pit is a very remarkable lode having a north-east and south-west direction, and being almost certainly a continuation of one of the Bunny mine lodes. A year or two back, this lode was even better exposed than at present (1951), the working of the pit having caused the upper portion to crumble away; even now, however, it is a striking object owing to the china-clay ground on either side of it having been washed away by the monitors. It

[1] A. Russell, On rashleighite, a new mineral from Cornwall, intermediate between turquoise and chalcosiderite. Min. Mag., 1948, vol. 28, pp. 356 and 357.

[2] M. H. Hey and F. A. Bannister, Russellite, a new British mineral. With a note on the occurrence and the accompanying minerals, by Arthur Russell. Min. Mag., 1938, vol. 25, p. 54.

[3] The occurrence of turquoise at Bunny mine was mentioned in a joint paper by myself and Dr. Vincent, On the occurrence of varlamoffite in Cornwall. Min. Mag., 1952, vol. 29, p. 819.

appears as a jagged wall of rudely crystallized greyish translucent quartz with somewhat comby structure, traversing the kaolinized granite, the width varying from 12 to 15 feet, but apparently thinning out at the south-west end of the pit.

Between the ribs of quartz there are in places both thin layers and thick impersistent bands of compact turquoise, the latter up to 7 cm. in thickness, which present a beautifully blue colour, especially when wet. In the open parts of the lode are considerable cavities lined with prismatic crystals of quartz covered with a layer of turquoise upon which are crusts of minute colourless or white needles and larger bladed crystals of wavellite, the remainder of the cavities being filled with white china-clay. Other specimens are remarkable in consisting of large masses of opaque white prismatic crystals of quartz cemented together by turquoise, these crystals when broken out leaving blue smooth prismatic casts. The turquoise also forms patches and veinlets in deep brownish vinaceous granular aggregates of cellular crystalline quartz.

There also occur large masses of turquoise presenting somewhat rounded surfaces and occasionally distinctly mamillary in form, and penetrated here and there by grey prisms of quartz, which in section show an outer secondary arrangement of small malformed crystals. These masses are often of a very pale blue to almost white colour from admixture with kaolinite, and are soft, being easily scratched even with the finger nail. The only other minerals observed in this lode are tourmaline and gilbertite, small needle brushes of the former rendering the quartz grey. Neither cassiterite nor wolframite appear to be present.

In the north-western end of the pit there appears to be another parallel lode similar in content, but this is at present obscured by loose material. Turquoise occurs in the debris and here I found a single thin sheet of native copper ($7\frac{1}{2} \times 4\frac{1}{2}$ cm.), this being the only metallic mineral I have observed in either lode: it is interesting as indicating a possible source of copper in the turquoise.

In the Hensbarrow china-clay pit, midway between Bunny mine and Gunheath, turquoise also occurs with thin layers of wavellite, but in much smaller quantity. It is derived from a lode at present not well exposed, but certainly identical with one of those of Bunny and Gunheath.

In thin section under the microscope the turquoise appears as a uniformly fine-grained aggregate of tiny acicular crystals, containing, as the analysis shows, even in the purest material a good deal of admixed kaolinite and an occasional small grain of quartz. Small cavities have

a mamillary crystalline surface. The specific gravity of the analysed material is 2·69–2·70.

The material polishes well, the colour being enhanced and yielding beautiful specimens. It is, however, difficult to obtain large uniform surfaces free from penetration of granular quartz, which in the process of polishing breaks out, leaving small hollows. The largest surface free from quartz which I have had polished measures about 11 × 5 cm.

The results of an analysis most kindly made by my friend Dr. E. A. Vincent, of the Department of Geology and Mineralogy, Oxford University, are contained in the following table. From this it will be seen that the Gunheath mineral has a composition very similar to that of the turquoise from Los Cerillos, New Mexico.

TABLE I. Chemical analyses of turquoise.

	I.	II.	III.	IV.	V.	VI.	VII.
P_2O_5 ...	26·76	—	—	26·76	33·82	34·12	33·72
As_2O_5 ...	trace	—	—	—	—	—	—
Al_2O_3 ...	35·05	—	8·19	26·86	33·94	36·84	32·75
Fe_2O_3 ...	3·22	—	—	3·22	4·07	—	4·28
FeO ...	0·13	—	—	0·13	0·16	—	0·71
CuO ...	7·79	—	—	7·79	9·84	9·57	7·54
CaO ...	n.fd.	—	—	—	—	—	—
MgO ...	n.fd.	—	—	—	—	—	—
SiO_2 ...	10·14	0·50	9·64	—	—	—	2·24
$H_2O^{+105°}$ ...	17·12	—	2·92	14·20	17·94	19·47	18·96
$H_2O^{-105°}$ ...	0·18	—	—	0·18	0·23	—	—
	100·39	0·50	20·75	79·14	100·00	100·00	100·20
Sp. gr. ...	2·69–2·70	—	—	—	—	—	2·697–2·764

I. Impure turquoise, Gunheath, St. Austell, Cornwall. (New analysis.)
II. To subtract for estimated 0·5 % quartz observed in thin section.
III. To subtract, assuming rest of SiO_2 present in kaolinite of theoretical composition $Al_2O_3.2SiO_2.2H_2O$.
IV. Remainder after subtracting II and III.
V. Column IV, recalculated to 100 %, and approximating to composition of turquoise in the mixture.
VI. Composition by weight of turquoise of theoretical composition

$$CuAl_6(PO_4)_4(OH)_8.5H_2O.$$

VII. Turquoise, Los Cerillos, New Mexico. H. Jung, Chemie der Erde, 1932, vol. 7, p. 81. [M.A. 5-279.]

In both the Gunheath and Los Cerillos turquoise there is some substitution of aluminium by ferric iron. X-ray powder photographs of the analysed Cornish material and of a fragment of the Los Cerillos turquoise have kindly been taken by Mr. A. W. G. Kingsbury, who reports

that he is unable to detect any difference whatever in the two patterns. The admixed kaolinite and quartz do not appear to have influenced the photograph obtained from the analysed Gunheath material.

The estimated composition of the analysed mixture is thus about 0·5 % quartz, 20·5 % kaolinite, and 79 % turquoise. If the recalculated analysis of the Gunheath turquoise (column V) is recast on a basis of 29 oxygen atoms, to compare with the theoretical composition (column VI) $CuAl_6P_4H_{18}O_{29}$, the following result is obtained:

$$Cu_{1\cdot05}(Al, Fe)_{6\cdot12}P_{4\cdot06}H_{17\cdot24}O_{29}.$$

This seems to be in reasonably satisfactory agreement with the theoretical formula for turquoise.