NOTES ON QUARTZ "DIKES"

G. M. Furnival, *Lochalsh, Ontario.*

Carl Tolman in a recent paper[1] on "Quartz Dikes" presents numerous cases from the literature of "quartz masses thought . . . to be of igneous origin." Tolman, by the phrase "quartz masses of igneous origin" refers to those masses of quartz which are believed to have formed by crystallization from an igneous melt, and uses it in contrast to "quartz veins" which have formed by deposition from highly aqueous solutions.

Physical-chemical grounds alone seem to preclude the possibility of quartz masses forming by direct crystallization from a melt. Pure silica has a melting point of 1713°C. so that existence in nature of molten silica seems highly improbable, and even were it possible its high viscosity would make injection unlikely. However, the articles quoted by Tolman and many additional articles were critically reviewed to determine the instance of such cases in the literature and the nature of the evidence upon which such conclusions are based.

The results of a study of the literature alone differ from those of Tolman and it was felt this paper would prove of interest to readers.

Occurrences of Large Quartz Masses

J. F. Kemp in 1899 and in 1901 described a huge mass of quartz at Lantern Hill, North Stonington, Connecticut.[2] Kemp regards it as the "ultra acid end-member of a pegmatitic-quartz vein series." Tolman quotes Kemp and cites this as an example of a "huge quartz vein a thousand feet in width which belongs in the pegmatitic series." However, he has failed to mention an excellent description of the vein by H. E. Gregory.[3] Gregory describes the vein as stockworks of quartz stringers up to fifteen hundred feet wide which has been traced several miles through aplitic granite gneiss. It consists of 98% quartz with patches of altered and partly replaced country rock. Gregory gives abundant evidence to support his conclusion that the vein has formed by a process of replacement of the gneiss by quartz deposited from hydrothermal solutions.

Tolman also cites as an example of "quartz dikes" tabular bodies of quartz near Foxdale, Isle of Man. These were probably first described by A. Harker as masses of pegmatite grading into quartz veins.[4] G. W. Lamplugh, in a later description, regards them as having formed from thermal waters rather than from a melt.[5] J. Lomas gives the most complete description of the veins and the alteration of their wall rocks.[6] The evidence indicates that quartz veins deposited from hydrothermal solutions grade into pegmatitic quartz veins as the source of the material is approached.

The "White Elephant Rock" near Salem, India, was first mentioned by King and Foote[7] and later by T. H. Holland.[8] Here are two large masses of quartz. The descriptions, however, are brief and incomplete and the evidence too scanty to justify the conclusion that these masses have an "igneous origin," in the sense defined by Tolman.

A paper on which Tolman places considerable emphasis is one by Baumgartel[9] in which is described an occurrence of quartz "veins" of two ages. The older, Baumgartel regards as an igneous intrusion or quartz "dike," the younger as a fissure filling deposited from hydrothermal solutions. The "veins" vary in width up to 20 cm. and are related to granite which intrudes Cambrian slates as isolated bosses. Baumgartel bases his conclusion that the older quartz bodies were intruded as igneous material on the alterations in the country rocks along them.

The Cambrian slates are metamorphosed by the granite to hornfels composed of quartz, muscovite, biotite, magnetite, tourmaline, zircon, calcite, rutile and carbonates with metacrysts of cordierite and garnet.

The quartz of the older bodies is coarse grained, clouded with liquid inclusions and has a cataclastic structure. The minerals present are apatite, spinel, magnetite, garnet, corundum, rutile, tourmaline, zircon, chalcopyrite, altered plagioclase, orthoclase and microperthite. The wall rock alteration superimposed on the contact metamorphism of the slates, and upon which the conception of the igneous origin of these bodies is based, consists of the enlargement in the grain size, alteration of the cordierite to pinite, of hornblende to calcite and chlorite, and the introduction of garnet, apatite, wolframite, scheelite and chalcopyrite. Biotite, tourmaline and zircon are increased in relative proportions.

Where quartz bodies which caused the above alteration in the metamorphosed slates pass into fresh slates they do not alter them. Baumgartel explains this by stating that the fresh slates were probably not at a sufficiently high temperature at the time of intrusion of the quartz. However, it is evident that the fresh slates represent a lower grade of metamorphism than the contact metamorphosed slates or hornfels, and, therefore, when exposed to the action of a melt (or high temperature solutions) it would seem that those rocks of lower grade metamorphism should undergo even more marked changes, and at least should be altered to the same degree as the hornfels. The evidence presented strongly suggests that the alteration described is due to other agencies than those from which the quartz bodies formed.

It seems that Tolman is not justified, on the basis of the evidence stated, in including these as "igneous quartz masses." The description suggests pegmatitic quartz veins followed by quartz veins.

That large masses of quartz have formed by the action of hydrothermal solutions is shown, in addition to the study of the large quartz vein at Lantern Hill, Connecticut, by studies of the Great Pfahl, the Bohemian Pfahl, and other large quartz veins of the Bohemian[10] and Hercynian[11] massifs of Bohemia and Brittany, by the "Great Sulphur Vein" of Ashton Moor in the Pennines of Northern England,[12] and by the large quartz veins of Great Bear Lake.[13]

The Bohemian Pfahl has been traced a distance of fifty-five kilometers and varies in width from 30 to 100 meters. The Great Pfahl has been traced for over 150 kilometers. A third large quartz vein in the Erzgebirge has been traced 40 kilometers. Bordering the eastern margin of the Amoracin massif of Brittany, Suess describes a large quartz vein 140 kilometers long. The "Great Sulphur Vein" varies from 128 feet to 1200 feet wide and is continuously exposed for eight miles. L. M. Thompson states that the vein is composed largely of quartz but contains some chalcopyrite, pyrite, pyrrhotite and galena.

At least fifty-five large quartz veins are known to occur in the Great Bear Lake area, Northwest Territories, Canada. These occur in the region from Fort Rae to Bathurst Inlet, 350 miles north to south and 250 miles east to west, and doubtless many more than this number exist. These veins have average widths in excess of 100 feet and lengths up to 17 miles. Including stockworks some exceed a thousand feet in width. The origin of the veins has been shown to be due to alteration and replacement of highly fractured rocks along faults of major displacement by quartz deposited from hydrothermal solutions at not very elevated temperatures.[13]

Quartz Masses Grading into Igneous Rocks

Tolman, in addition to numerous cases of masses of quartz which grade into pegmatite dikes and which will be discussed later, cites three cases in which the quartz masses are described as grading into stocks or laccoliths of igneous rocks.

One such case which he refers to is that described by A. L. Hall[14] of an "ultra-acid" or highly quartzose rock which occurs widely distributed around the margins of the Bushveldt granite in Western Secoecoeniland, South Africa. However, in literature by A. L. Hall[15] and A. L. Du Toit,[16] subsequent to that quoted by Tolman, the "ultra-acid" rocks are shown to be highly altered recrystallized quartzites.

A second case is the rock "northfieldite" described by B. K. Emerson[17] from western Massachusetts, as a "band of contact quartz rock" which occurs around the margins and within a granite batholith in part gneissic, the Pelham granite. The rock occurs between the gneissic granite and a highly metamorphosed series of sediments. Emerson bases his classification of it as an igneous rock only on the general distribution around the margins of the granite. He states that its coarser varieties resemble vein quartz, its finer a quartzite. His description of the mineralogy, textures and structures of the rock, and its conformable relations at places with the metamorphosed series of sediments, strongly suggest that this rock is a partially recrystallized quartzite. In fact Emerson himself states that "for a long time I considered the whole series including the . . . northfieldite to be sedimentary," but fails to state any reason for changing his opinion.

A rock which surrounds the Monson granite batholith, south of the Pelham mass, described by Emerson as a diorite, has been shown recently to have formed by the replacement of limestone.[20]

Emerson later described another occurrence of "northfieldite."[19] He finds the Milford granite in Massachusetts is "bordered by a zone of dark hornblendic quartz diorite, within which is another zone, about a mile wide, consisting mainly of fine grained, light colored aplite, much of it so poor in feldspar that it resembles a slightly biotitic quartzite." This is called "northfieldite." Emerson again bases his conclusion as to its igneous origin on its distribution as a concentric zone between the granite and the "hornblendic border zone." However, he states that "it is difficult to distinguish it either in the field or under the microscope from the nearby Algonkian quartzite." He also mentions the abundance of rutile needles in the quartz grains, a common characteristic of quartz of sedimentary rocks.[21]

It seems probable from a study of the descriptions that "northfieldite" is contact metamorphosed quartzite.

The third case cited by Tolman is that described by Dwerryhouse[22] of a granite laccolith near Eskdale, England, which has a highly quartzose border phase in contact with volcanic rocks which it intrudes. The quartzose rock is transitional into the granite, but is fine grained at its outer margin and has a sharp contact with the volcanics. The interpretation of the quartzose rock as "an early phase of the granite and, therefore, an igneous rock" is based upon its areal distribution relative to the granite.

B. Simpson in a recent and more thorough study of the granite[23] finds there has been considerable assimilation of the country rocks and contaminated granite is common. He describes the presence of a fine grained micaceous quartzose rock, which at places is almost pure quartz, as parts of the margin and as irregular patches within the granite mass. At places he finds there is a sharp line between this rock and normal granite and at other places there is no sharp demarcation between the two types. Though he agreed there were places where the granite is exceedingly fine grained and acid, he disagreed with Dwerryhouse's generalization that the granite becomes more acid as the margin is approached. Simpson is inconclusive regarding the origin of the acid rock.

Though Simpson concludes the granite is laccolithic in shape, the evidence he presents, as pointed out by S. E. Hollingsworth, in the discussion of the paper, would favor the view that the mass has the shape of a stock.

Since the origin of the quartzose rock has not been satisfactorily settled, and in view of the conflicting nature of the most recent descriptions of the rock, it is not considered that Tolman is justified on the basis of Dwerryhouse's description in classing this rock as a quartz mass grading into an igneous rock. Furthermore, it is significant that the rocks which underly the intruded volcanics are quartzose sandstones.[24] These are the oldest rocks exposed in the area. Since the granite may have the form of a stock, it is quite possible that the quartzose rock described above may be the partially assimilated quartzose sandstone left as recrystallized remnants in and at the margins of the granite.

Quartz Veins Grading into Pegmatites

Tolman quotes the "silexite" masses described by W. J. Miller,[25] from the northern part of New York State as quartz masses of "igneous origin."

Miller applies the term "silexite" to "any body of pure or nearly pure quartz or silica of igneous or aqueo-igneous origin which occurs as a dike, segregation mass, or inclusion within or without its parent rock," and states " . . . the evidence that they are not true veins is decisive. None of them ever shows crustification and many of them grade into true pegmatite." The absence of crustification of course does not prove that the quartz has not been deposited from aqueous solutions, and no evidence is presented to support the view that these bodies are not ordinary quartz veins which in many cases grade into pegmatite dikes.

Tolman cites many cases of quartz which grade into pegmatite and feldspar-quartz masses. These and additional references are presented in the following list which is doubtless far from complete:

C. R. Van Hise[26]; Black Hills of South Dakota
Adams and Barlow[27]; Ontario
P. Billingsley[28]; Montana.
L. H. Ogilvie[29]; New York.
J. F. Kemp[30]; Atlantic Coast.
H. C. Cooke[31]; Northern Ontario.

A. A. Pegau[32]; Virginia.
F. Zirkel[33]; Pyrenees.
H. Credner[34]; Saxony.
J. J. Sederholm[35]; Finland.
G. Klemm[36]; Germany and the Alps.
G. H. Williams[37]; Maryland.
J. E. Spurr[38]; Alaska and Nevada.
W. Cross[39]; Colorado.
A. C. Spencer[40]; Wyoming.
Spurr and Garrey[41]; Colorado.
Lindgren and Ransome[42]; Colorado.
F. H. Lahee[43]; Rhode Island.
B. S. Butler[44]; Utah.
F. A. Thompson and S. M. Ballard[45]; Idaho.
J. S. Brown[46]; Alabama.
H. Rosenbusch[47]; Ural Mountains.
E. S. Bastin[48]; Maine.

This relationship has been assumed to indicate an "igneous origin" for such quartz bodies. However, recent work by Schaller,[49] Hess,[50] Landes,[51] Anderson,[52] Wagner,[53] Derry[54] and others have shown that pegmatites form in large part by replacement from hydrothermal solutions, particularly the later stages which involve the deposition of minerals of the rare elements. Derry shows that quartz, one of the earliest minerals in the "complex pegmatites" of eastern Manitoba, is of the low temperature type and, therefore, most of the minerals have been deposited at comparatively low temperatures, at least below 575°C. He presents experimental evidence to show that there is little effect on the mutual lowering of melting points by any minerals present, all of which have high melting points, and concludes that the minerals must have been deposited from relatively weak aqueous solutions.

Pegmatites Grading into Metalliferous Quartz Veins

Tolman cites Spurr's description of the Silver Peak mines, where Spurr finds gold bearing veins grading into alaskite.[55] However, Tolman has failed to mention a paper by J. B. Hastings,[56] who examined the mines at a later date. Hastings presents evidence to show the quartz veins are deposited along sheared zones formed after the alaskite masses, and that the quartz veins do not pass transitionally into alaskite.

Three occurrences described by Butler,[57] Graton,[58] and Howitt,[59] of metalliferous quartz veins which grade into pegmatite are mentioned by Tolman. In discussing such transitions G. F. Loughlin and C. H. Behre, Jr.,[60] state that if any transitions between metalliferous veins and pegmatites have been proved, they are extremely rare. They state that, "The usual structural relations where metalliferous deposits of appreciable size are closely associated with pegmatites show that the metalliferous minerals, especially the sulphides, were introduced at a distinctly later stage than the pegmatitic quartz, by solutions derived from a deeper source than that of local quartz."

Summary

Studies of the large quartz veins of Connecticut, Great Bear Lake, and elsewhere show that large quartz masses have formed by the action of hydrothermal solutions. The evidence regarding several large masses of quartz cited by Tolman as of "igneous origin" is inconclusive.

Large quartz masses formerly thought to grade into igneous rocks and to have formed from igneous melts are shown by recent work to be recrystallized quartzites. None of the other cases cited by Tolman of gradation of igneous rocks into quartz bodies seem entirely convincing, nor have any others been found in a search of the literature on quartz bodies.

Many examples of quartz bodies, only a few of them metalliferous, which grade into pegmatites, have been described. However, in view of the recent work which emphasizes the large part hydrothermal solutions play in the formation of pegmatites, it is evident that this relationship can no longer be considered to prove an "igneous origin" for the quartz bodies.

Conclusion

No occurrence of a body of quartz which has undoubtedly formed by the action of magmatic processes, that is by direct crystallization from an igneous magma, has been described in geologic literature.

References

[1] Tolman, Carl, Quartz dikes: *Am. Mineral.*, **16,** 278 (1931).

[2] Kemp, J. F., Granites of the Atlantic coast: *Bull. Geol. Soc. Am.*, **10,** 375 (1899). The role of the igneous rocks in the formation of veins: *Trans. A.I.M.E.*, **31,** 182 (1901).

[3] Rice, W. N., and Gregory, H. E., Manual of the Geology of Connecticut: *Conn. Geol. and Nat. Hist. Sur., Bull.* No. **6,** 136 (1906).

[4] Harker, A., Carrock Fell granophyre and Grainsgill greisen: *Quart. Jour. Geol. Soc.*, **51,** 143 (1895).

[5] Lamplugh, G. W., Geology of the Isle of Man: *Mem., Geol. Sur. United Kingdom,* 320 (1903).

[6] Lomas, J., Quartz dykes near Foxdale, Isle of Man: *Geol. Mag.*, **10,** 34 (1903).

[7] King and Foote, *Geol. Sur. of India, Mem.* **5,** Pt. 2, 117, (1864).

[8] Holland, T. H., Geology of the neighborhood of Salem: *Geol. Sur. of India, Mem.* **30,** 137 (1901.)

[9] Baumgartel, Von H. B., Eruptive Quartzgange in der Umgebung der vogtlandisch-westerzgebirgischen Granitmassive: *Zeits. deut. geol. Ges.*, **63 (a)** 175 (1911).

[10] SUESS, E., The Face of the Earth, **1,** 204–209 (1904).
[11] SUESS, E., The Face of the Earth, IV, 49 (1904).
[12] THOMPSON, L. M., The great sulphur vein of Alston Moor: *Proc. University of Durham Philosophical Society*, **9,** 91–98 (1934).
[13] FURNIVAL, G. M., Large quartz veins of Great Bear Lake, N.W.T., Canada: *Econ. Geol.*, **30,** 843–859 (1935).
[14] HALL, A. L., Notes on certain wide-spread ultra-acid rocks occurring along the margin of the Bushveldt granite in western Secoecoeniland: *Trans. Geol. Soc. South Africa*, **13,** 10 (1910).
[15] HALL, A. L., *Trans. Geol. Soc. South Africa*, **24,** 228 (1922).
The Bushveldt igneous complex: *Int. Geol. Cong. Guide Book, 15th Session, South Africa, Excursion C. 19*, 32, 61, 62, and 65 (1929).
[16] DU TOIT, A. L. Geology of South Africa, 140 (**1926**).
[17] EMERSON, B. K., Northfieldite, pegmatite and pegmatite schist: *Am. Jour. Sci.*, **40,** 212–217 (1915).
[18] *Idem*, 214.
[19] EMERSON, B. K., Geology of Massachusetts and Rhode Island: *U.S.G.S.*, *Bull.* **597,** 167 (1917).
[20] BERKEY, C. P., and FAHLQUIST, F. E., A geologic section of the Quabbin aqueduct in central Massachusetts: presented *Nat. Acad. Sciences*, 5th Scientific Session, Autumn meeting, Cambridge, Mass. (**1933**).
The Eastern Appalachian geosyncline: *16th. Int. Geol. Cong.*, Abstracts of papers, 42 (**1933**).
[21] MILNER, H. B., Sedimentary Petrography: 226 (1929).
[22] DWERRYHOUSE, A. R., Intrusive rocks in the neighbourhood of Eskdale, England: *Quart. Jour. Geol. Soc.*, **65,** 64, (1909).
[23] SIMPSON, B., The petrology of the Eskdale (Cumberland) granite: *Proc. Geol. Assoc.*, **45,** 17 (1934).
[24] GREEN, J. F. N., The geological structure of the Lake District: *Proc. Geol. Assoc.*, **31,** 109 and 112 (1920).
[25] MILLER, W. J., Pegmatite, silexite, and aplite of northern New York: *Jour. Geol.*, **27,** 27–54 (1919).
[26] VAN HISE, C. R., Principles of North American Precambrian geology: *U.S.G.S.*, *16th Ann. Rept.*, Pt. **1,** 687 (1894–5).
[27] ADAMS and BARLOW, Geology of the Haliburton and Bancroft areas, Ontario: *Mem.* **6,** *Geol. Sur. of Canada*, **145** (1910).
[28] BILLINGSLEY, P., The Boulder batholith of Montana: *Trans. A.I.M.E.*, **51,** 43 (1915).
[29] OGILVIE, L. H., Paradox Lake quadrangle, New York: *New York State Museum, Bull.*, **96,** 487 (1905).
[30] KEMP, J. F., Pegmatites and aplites of the Atlantic coast: *Bull. Geol. Soc. Amer.*, 374, (1899).
[31] COOKE, H. C., Geology of the Matachewan area, northern Ontario: *Geol. Sur. Can.*, *Mem.* **115,** 47 (1919).
[32] PEGAU, A. A., Pegmatite deposits of Virginia: *Virginia Geol. Sur. Bull.* **33,** 10 (1932).
[33] ZIRKEL, F., Beiträge zur Geologischen Kenntnis der Pyrennaen: *Zeits. deut. geol. Ges.*, **19,** 105 (1867).
[34] CREDNER, H., Die Granitischen Gange des sachsischen Granulitgebirges: *Zeits. deut. geol. Ges.*, **27,** 176 (1875).
[35] SEDERHOLM, J. J., Über die findlandischen Rapakiwigesteine: *Tschermacks Min.-Petr. Mitteil.*, **12,** 8 (1891).

[36] KLEMM, G., Beiträge zur Kenntnis des krystallinen Grundgebirges im Spessart: *Abh. Groszherzogl. hessischen Geol. Landenstalt*, **2,** 190 (1891–5).
Über der Gneisse und Schiefer der Tessiner Alpen: *Sitzungsber. Königlich Preuss. Akad. Wissens.*, 56 (**1904**).
[37] WILLIAMS, G. H., The general relations of the granite rocks in the middle Atlantic Piedmont plateau: *U.S.G.S., 15th Ann. Rept.*, 670 (**1895**).
[38] SPURR, J. E., Geology of the Yukon gold district, Alaska: *U.S.G.S., 18th Ann. Rept.*, Pt. **3,** 147 (1896–7).
Quartz muscovite rock from Belmont, Nevada: *Am. Jour. Sci.*, **10,** 351 (1900).
Southern Klondike district, Nevada: *Econ. Geol.*, **1,** 370 (1906).
[39] CROSS, W., Geology of the Silver Cliff and the Rosita Hills, Colorado: *U.S.G.S., 17th Ann. Rept.*, Pt. **2,** 279 (1896).
[40] SPENCER, A. C., Ore deposits of the Encampment district, Wyoming: *U.S.G.S., P.P.* **25,** 41 (1904).
[41] SPURR, J. E., and GARREY, G. H., Preliminary report on the ore deposits in the Georgetown, Colorado, mining district: *U.S.G.S., Bull.* **260,** 104 (1905).
[42] LINDGREN, W., and RANSOME, F. L., Geology and gold resources of the Cripple Creek district, Colorado: *U.S.G.S., P.P.* **54,** 43 (1906),
[43] LAHEE, F. H., Relations of the degree of metamorphism to geological structure and to acid igneous intrusions in the Narragansett Basin, Rhode Island: *Am. Jour. Sci.*, **33,** 451-61 (1912).
[44] BUTLER, B. S., The ore deposits of Utah: *U.S.G.S., P.P.* **111,** 159 (1920).
[45] THOMPSON, F. A., and BALLARD, S. M., Geology and gold resources of north central Idaho: *Idaho Bur. Mines and Geol., Bull.* **7,** 41 (1924).
[46] BROWN, J. S., Graphite deposits of Ashland, Alabama: *Econ. Geol.*, **22,** 224 (1925).
[47] ROSENBUSCH, H., Elemente der Gesteinslehre, Stuttgart, 207 (**1898**).
[48] BASTIN, E. S., Geology of pegmatites and associated rocks of Maine: *U.S.G.S., Bull.* **445,** 19 and 66 (1911).
[49] SCHALLER, W. T., The genesis of lithium pegmatites: *Am. Jour. Sci.*, **10,** 269–279 (1925).
Mineral replacements in pegmatites: *Am. Mineral.*, **12,** 59–63 (1927).
[50] HESS, F. L., Natural history of pegmatites: *Eng. Min. Jour. Press*, **120,** 289–296 (1925).
[51] LANDES, K. K., The paragenesis of the granite pegmatites of central Maine: *Am. Mineral.*, **10,** 355–417 (1925).
[52] ANDERSON, A. L., Genesis of the mica pegmatite deposits of Latah County, Idaho: *Econ. Geol.*, **28,** 41–58 (1933).
[53] WAGNER, P. A., The Union of South Africa: *Handb. d. regionalen Geol.*, **7,** 7(a), 193–200 (1929).
[54] DERRY, D. R., The genetic relationships of pegmatites, aplites and tin veins: *Geol. Mag.*, **68,** 454–475 (1931).
[55] SPURR, J. E., Ore deposits of Silver Peak quadrangle: *U.S.G.S., P.P.* **55,** 44 (1906).
[56] HASTINGS, J. B., Are the quartz veins of Silver Peak, Nevada, the result of magmatic segregation?: *A.I.M.E.*, **36,** 44 (1906).
[57] BUTLER, B. S., The ore deposits of Utah: *U.S.G.S., P.P.* **111,** 159 (1920).
[58] GRATON, L. C., The occurrences of copper in Shasta County, California: *U.S.G.S., Bull.* **430,** 86 (1909).
[59] HOWITT, A. W., Notes on the area of intrusive rocks at Dargo: *Trans. Roy. Soc. Victoria*, **23,** 152 (1887).
[60] LOUGHLIN, G. F., and BEHRE, C. H., Jr., Classification of ore deposits: *A.I.M.E., Lindgren Volume*, Ore deposits of the Western States: 52 (**1933**).