ORIGIN AND CLASSIFICATION OF PEGMATITES
(Concluded)

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CLASSIFICATION OF PEGMATITES

Introduction

The natural tendency in classifying pegmatites is to use the same nomenclature as is used in rock classification, with (in the case of the pegmatites producing rare minerals) a sub-classification based upon the prevailing type of minerals present. Such classifications have been made by Harker[105] and Palache.[106] Lacroix[107] has developed a chemical classification which is followed by some. An interesting genetic classification has been recently published by Piatnitsky.[108] It follows:

I. Monophasic pegmatites: (a) liquid magma pegmatites; (b) pneumatolytic pegmatites; (c) hydrothermal pegmatites.
II. Polyphasic pegmatites.

In his important contribution on the geochemical-genetic classification of granite pegmatites, Fersman[109] includes a general classification of pegmatites produced by seven different magmas ranging from basic to acidic. He further subdivides granite pegmatites into seven groups and 30 types. The principal basis for the group separation is the presence or absence of contact effects (i.e. "pure" pegmatites, contact pegmatites, migmatic pegmatites) while the types are divided on a basis of characteristic elements or minerals.

The classification submitted below is similar to those of Harker and Palache, with the addition of a division into simple and complex. Simple pegmatites are defined as those in which there has been no hydrothermal replacement. The complex group includes most of the more famous pegmatites, for in them hydrothermal replacement has taken place and rarer minerals have been deposited. The simple pegmatites are classified into rock types according to the relative importance of the mineral constituents. The complex peg-

[105] Harker, A., Natural history of igneous rocks, *New York*, p. 298, **1909.**

[106] Palache, Charles, Advanced mineralogy lecture notes, **1923.**

[107] Lacroix, Alfred, Mineralogie de Madagascar, *Paris*, **1922.**

[108] Piatnitsky, P., *Op. cit.*

[109] Fersman, A. E., Ueber die geochemisch-genetische Klassification der Granitpegmatite: *Min. Petr. Mitt.* (*Tschermak*), **41,** 64–83, 1931. Especially Tables I and VI.

matites are similarly classified, except that the hydrothermal minerals, no matter how abundant, are not considered in making the primary grouping. The hydrothermal minerals form the basis for dividing the complex pegmatites into subgroups.

Acidic pegmatites are far more abundant than basic, for two reasons: (1) acidic intrusive magmas are much commoner, and (2) as a general rule pegmatites are more acidic than the plutonic body from which they have been derived. As an illustration of the latter, small bodies of pegmatite containing a little quartz occur in the anorthosites of the Adirondack Mountains,[110] cutting the Medford diabase dike[111] and in the country rock underlying the Duluth gabbro.[112] Numerous other examples might be cited.

The cubic volume occupied by complex pegmatites is insignificant when compared with that occupied by simple pegmatites. Naturally, because of the much greater mineralogical interest, the complex pegmatites receive many pages of description in geological literature, while the common pegmatites are but rarely mentioned. Most of the injected (lit-par-lit) pegmatites are of the simple type. The Harney Peak granite in the Black Hills is pegmatitic in texture and its volume is many times the volume of the several complex pegmatites that lie in the surrounding metamorphic rock. The rocks of Maine contain many pegmatites of which the vast majority are of the simple type. Derry[113] has noted the preponderance of simple pegmatites in the pegmatite area of southeastern Manitoba.

Classification

A. *Acid* (alaskite, normal granite, alkaline granite, granodiorite, quartz monzonite, and quartz diorite)
   1. Simple
   2. Complex, with following phases (aside from albitization): lithium, fluorine, beryllium, boron, phosphate, graphite, rare earth, ore mineral, and quartz vein

[110] Barth, Tom F. W., Mineralogy of the Adirondack feldspars: *Am. Mineralogist*, **15**, no. 4, pp. 136, 1930. Alling, H. L., The Adirondack anorthosite and its problems: *Jour. Geol.*, **40**, no. 3, p. 206, 1932.

[111] Jaggar, T. A., Jr., an occurrence of acid pegmatites in diabase: *Am. Geol.*, **21**, p. 205, 1898.

[112] Grout, F. F., The pegmatites of the Duluth gabbo: *Econ. Geol.*, **13**, p. 187, 1918.

[113] Derry, *Op. cit.*

B. *Intermediate* (syenite, alkaline syenite, monzonite, diorite)
  1. Simple
  2. Complex, with following phases: rare alkaline mineral, calcite, radioactive mineral, and sulphide

C. *Basic* (gabbro, diabase, anorthosite, and pyroxenite)
  1. Simple
  2. Complex (calcite-apatite-phlogopite phase)

Discussion

Under acid pegmatites are included all those that contain free quartz as a primary mineral. As in the case of the normal igneous rocks gradations occur between varieties. The division between granite and granodiorite pegmatites is complicated by the failure of many writers to name the varieties of feldspar present or to distinguish between magmatic and hydrothermal albite. Alaskite and common granite pegmatites are by far the most abundant. The former contain quartz and potash feldspar as the sole magmatic constituents, while the granite pegmatites contain in addition accessory minerals such as muscovite, biotite, garnet, and perhaps common beryl and black tourmaline. The latter two minerals definitely belong to the magmatic stage in pegmatites studied by the writer, although the same species may reappear, often in gem worthy specimens, in later hydrothermal phases. Examples of alaskite pegmatites occur at Baringer Hill, Texas; New Ross, Nova Scotia;[114] and Silver Peak, Nevada. The Silver Peak occurrence has been described by Spurr,[115] who originated the word alaskite a number of years earlier. According to Schaller's[116] paragenetic interpretation, the pegmatites at Pala, California, are alaskite in character. Ordinary granite pegmatites are found on every continent, and are most important sources of muscovite. A good example of this type, occurring in Siberia, has recently been described by Misharev.[117] Alkalic granite pegmatites occur in eastern Massa-

[114] Cook, C. W., Molybdenite deposit near New Ross, Nova Scotia: *Econ. Geol.*, **20**, p. 186, 1925.

[115] Spurr, J. S., The Ore-Magmas, *New York*, p. 325, **1923.**

[116] Schaller, W. T., The genesis of lithium pegmatites: *Amer. Jour. Sci.*, **10**, pp. 269–279, Sept. 1925. Mineral replacements in pegmatites: *Am. Mineralogist*, **12**, pp. 59–63, March, 1927.

[117] Misharev, D. T., Mama-Vitun-Chuisky deposits of mica: *Trans. United Geol. and Prosp. Service, U. S. S. R. Fascicle* **154**, pp. 1–89, 1932.

chusetts and in Oklahoma.[118] Pegmatites which may be classified as granodiorite occur near Milford, New Hampshire,[119] and in Riverside County, California.[120] Quartz diorite pegmatites occur in the Adirondacks[121] and in northwestern Manitoba.[122]

All of the complex acid pegmatites known to the writer exhibit albitization, and in most instances the hydrothermal solutions have produced a series of additional minerals. These may be divided into groups based upon position in the depositional sequence and similarities in chemical composition. In many pegmatites these groups are so well developed that the pegmatite is spoken of as having a lithium phase, or a phosphate phase, or some other phase. In some pegmatites two and even three phases may be represented, while in others the mineral species may be so scattered among the different groups that none are outstanding. Probably the most prominent phase in acid pegmatities is the lithium phase. Examples are Pala, California; Embudo, New Mexico; Keystone, South Dakota; southeastern Manitoba; central Maine; Madagascar; Wodgina, Western Australia; Lunenburg County, Nova Scotia; Üto, Sweden; east Transbaikalia;[123] and Pontevedra, Spain.[124]

Pegmatites on St. Peter's Dome in the Colorado Springs area and in the Urga district in Mongolia[125] have a fluorine phase, and at Ivigtut in southwestern Greenland this phase has produced cryolite to the exclusion of the usual quartz and feldspar. Topaz and fluorite are common accessory minerals in many pegmatites in which phases other than fluorine are dominant.

Although the writer believes common beryl to belong to the

[118] Rogers, A. F., Aegirite and riebeckite rocks from Oklahoma: *Jour. Geol.*, **12,** p. 286, 1907.

[119] Dale, T. N., The granites of Massachusetts, New Hampshire, and Rhode Island: *U. S. Geol. Survey, Bull.* **354,** p. 48, 1908.

[120] Dykes, Leland H., Occurrence of monazite in a granodiorite pegmatite: *Pan-American Geologist*, vol. **58,** p. 74, Aug. 1932.

[121] Alling, Harold L., Genesis of the Adirondack magnetites: *Econ. Geol.*, **20,** p. 346, 1925.

[122] Wright, J. F., Geology and mineral deposits of a part of northwestern Manitoba: *Can. Geol. Survey, Summ. Rept. 1930*, pt. C, p. 20, **1931.**

[123] Orteniev, B., Materials to the knowledge of the tin deposits of east Transbaikalia: *U. S. S. R. Geol. and Pros. Service, Bull.* **49** (7), 29–45, 1930.

[124] Gibson, W. B., A new occurrence of spodumene: *Rocks and Minerals*, **7,** no. 1, p. 23, 1932.

[125] Kryjanowsky, V., Sur les pegmatites des environs d'Urga en Mongolia: *Compt. Rend. Acad. Sci. Russie*, pp. 13–16, **1925.** (Abs. *Min. Abstr.*, **3,** p. 439).

magmatic stage of pegmatite development, the white beryl of the Keystone district in the Black Hills, the cesium beryl and rare beryllium minerals of central Maine, the gem beryls of Madagascar, and the aquamarines and emeralds of Brazil, Colombia,[126] and the Urals are considered to be products of a hydrothermal beryllium phase. Dittler and Kirnbauer[127] have recently described pegmatites in Roumania containing beryl in two generations. Likewise gem tourmalines and associated rare boron minerals are considered to result from a boron phase in complex pegmatites. Examples of this are Pala, California; central Maine; Haddam, Connecticut; Brazil; Elba; and Ekaterinburg, Russia.

A well developed phosphate phase is not common, although apatite is a widespread pegmatite mineral. Examples of phosphate pegmatites are: Buckfield, Newry, and Poland, Maine; Branchville, Connecticut; Limoges, France; eastern Bavaria;[128] and Bohemia.[129]

Graphite in Quebec pegmatites, deposited there by solutions of pegmatitic origin, is described by Bain.[130]

A rare earth phase occurs in the granite pegmatites of southern Norway; Ytterby, Sweden; and Llano County, Texas, and in an alkalic granite pegmatite at Cape Ann, Massachusetts.[131] In addition, a great many other pegmatites, such as those in Madagascar, contain a few rare earth minerals.

Hydrothermal magnetite is abundant in some pegmatites (as at Llano County, Texas) and in the New Jersey Highlands it occurs in masses of sufficient concentration to constitute iron ore.[132] The occurrence in pegmatites of cassiterite and wolframite with other high temperature ore minerals is a matter of common knowledge.

[126] Piatnitsky, P., *Op. cit.*

[127] Dittler, E., and Kirnbauer, F., Ueber das neue Beryllvorkommen von Teregova in Rumänien: *Z. Prakt. Geol.*, **39**, (4), 49–56, 1931. Abs. in *Annot. Bibliog., Econ. Geol.*, **4**, 1, p. 517.

[128] Laubmann, H. und Steinmetz, H., Phosphatführende Pegmatite des Oberpfälzer und Bayerischen Waldes: *Zeit. Kryst. Min.*, **55**, p. 584, 1915–1920.

[129] Sellner, Fritz, Die Pegmatite der Umgebung von Marienbad: *Zeits. Krist.*, **59**, pp. 504–512; **60**, pp. 275–277, 1924. (Abs. *Min. Abstr.*, **2**, p. 472.)

[130] Bain, G. W., *Op. cit.*

[131] Warren, C. H., and McKinstry, Hugh, The granites and pegmatites of Cape Ann, Mass.: *Am. Acad. Arts & Science Proc.*, **59**, no. 14, p. 344, 1924.

[132] Bayley, W. S., Iron mines and iron mining in New Jersey: *N. J. Survey, Final Report*, **7**, 1910.

Localities illustrating this are Washington State,[133] Nova Scotia,[134] Saxony,[135] Bolivia,[136] Cornwall,[137] New South Wales,[138] South Africa, and Malaya. Molybdenite occurs in pegmatites in Colorado;[139] Nova Scotia;[140] Quincy, Massachusetts;[141] Pontiac County, Quebec;[142] and many other localities. It often has associated with it other sulphides, such as pyrite, galena, sphalerite and chalcopyrite. The pegmatites associated with the quartz diorite of Shasta County, California, "in places pass over into siliceous masses that are virtually quartz veins and carry sulphides."[143] Gold has been noted in a number of pegmatites. Examples are Park Valley and Spring Creek districts, Utah;[144] Silver Peak, Nevada;[145] Minas Geraes; Brazil;[146] and Dartmoor, England.[147] The Dartmoor pegmatite is quartz monzonite in composition.

[133] Anderson, A. L., Genesis of Silver Hill tin deposits: *Jour. Geol.*, **36,** pp. 646–664, Oct.-Nov., 1928.

[134] Faribault, R., Lunenburg County, Nova Scotia: *Can. Geol. Survey, Summary Rept.* **1907,** pp. 78–83, 1908.

[135] Vogt, J. H. L., The physical chemistry of the magmatic differentiation of igneous rocks: *Skrifter utgitt av Det Norske Videnskops-Akademi i Oslo I, Mat.-Naturv. Klasse,* no. **3,** second half, 1930, p. 67.

[136] Ahlfeld, F., Supergene cassiterite in tin veins: *Econ. Geol.*, **25,** pp. 546–548, Aug. 1930.

[137] Davison, E. H., Mineral associations in Cornish tin lodes: *Mining Mag.*, **43,** pp. 143–149, 1930.

[138] Cotton, L. A., The tin deposits of New England: *Proc. Linnean Soc. N. S. W.*, **34,** pt. 4, Nov. 24, 1909. (quoted by Lindgren, W.: Mineral Deposits, 3d ed., p. 850).

[139] Butler, B. S., and Vanderwilt, J. W., The climax molybdenite deposit of Colorado: *Colo. Sci. Soc. Proc.*, **12,** no. 10, pp. 309–353, 1931.

[140] Cook, C. W., Molybdenite deposit near New Ross, Nova Scotia: *Econ. Geol.*, **20,** pp. 185–188, 1925.

[141] Warren, C. H., and Palache, Charles, The pegmatites of the riebeckite-aegirite granite of Quincy, Massachusetts, U. S. A.; their structure, minerals, and origin: *Am. Acad. Arts & Science Proc.*, **47,** pp. 125–168, 1911.

[142] Thomson, E., A pegmatite origin for molybdenum ores: *Econ. Geol.*, **13,** pp. 302–313, 1918.

[143] Graton, L. C., The occurrence of copper in Shasta County, California: *U. S. Geol. Survey, Bull.* **430-B,** p. 86, 1909.

[144] Butler, B. S., Ore deposits of Utah: *U. S. Geol. Survey, Prof. Paper* **111,** p. 159, 1920.

[145] Spurr, J. S., The Ore-Magmas, *New York,* **1923.**

[146] Derby, Orville A., On the mineralization of the gold-bearing lode of Passagem, Minas Geraes, Brazil: *Amer. Jour. Sci.*, 4th ser., **32,** pp. 185–190, 1911.

[147] Brammall, A., and Harwood, H. F., The occurrence of a gold-bearing pegmatite on Dartmoor: *Mineralog. Mag.*, **20,** pp. 201–211, 1924.

The gradation of ore-bearing pegmatites into quartz veins has already been noted. Such veins are considered to represent a phase in the mineralization of complex pegmatites. Many examples of gradations between pegmatites and quartz dikes have been cited by Tolman.[148] An important addition to this list is a Transbaikalian occurrence recently described by Holmov.[149] Three periods of mineralization are postulated: (1) Pegmatite period. (2) Period of magmatic siliceous solutions, during which tourmaline-quartz, tungsten-quartz, and arsenopyrite-tourmaline veins were deposited. (3) Period of gel solution, during which fluorite-hornblende zones and veins of cryptocrystalline quartz were formed.

Common syenite pegmatites are rare because the pegmatitic offshoots of syenitic magmas are generally more siliceous than the original magmas so that quartz forms during crystallization. Thus the pegmatites associated with the syenite masses of north central Wisconsin[150] contain quartz and should, therefore, be classified as alkalic granite pegmatites. The nephelite-syenites of the same area, however, have associated pegmatites which are simple nephelite-syenite in composition, and the nephelite-syenite of the Haliburton and Bancroft areas, Ontario, contains both simple and complex pegmatitic facies.[151] Gillson[152] has described diorite pegmatites occurring in the Adirondacks, and the "soda pegmatites" of Bastin[153] which occur on both sides of the state line between Maryland and Pennsylvania could perhaps be similarly classified. Other examples are the amphibole pegmatites occurring in northwestern Manitoba[154] and in the Obi Islands in the Moluccas.[155]

From a mineralogical point of view, the most interesting of the

[148] Tolman, Carl, Quartz dikes: *Am. Mineralogist*, **16**, pp. 278–299, 1931.

[149] Holmov, George, Minerogenetic sketch of Duldurga tungsten deposit (Transbaikalia): *Trans. United Geol. and Prosp. Service of U.S.S.R. Fascicle* **133**, 1931, (English summary, pp. 35–36).

[150] Weidman, S., The geology of north central Wisconsin: *Wis. Geol. and Nat. Hist. Survey, Bull.* **16**, pp. 1–697, 1907.

[151] Adams, Frank D., and Barlow, Alfred E., *Op. cit.*

[152] Gillson, J. L., Callahan, W. H., and Millar, W. B., Adirondack studies: *Jour. Geol.*, **36**, pp. 149–164, 1928.

[153] Bastin, Edson S., Economic geology of the feldspar deposits of the United States: *U. S. Geol. Survey, Bull.* **420**, 1910.

[154] Wright, J. F., *Op. cit.*

[155] Brouwer, H. A., Bijdrage tot de geologie der Obi-eilanden: *Jaarboek von het Mijnwezen in Nederlandsch Oost-Indie*, **52**, pp. 3–62, 1924. (Abs. *Min. Abstr.*, **3**, 1, pp. 37–38.)

complex intermediate pegmatites are those with a rare alkaline mineral phase, such as the alkaline-syenite pegmatites of the Fredriksvärn and Langesundsfjord districts in southeastern Norway.[156] Somewhat similar pegmatites occur in the Kola Peninsula, Russia;[157] and at Magnet Cove, Arkansas.[158] The complex sodalite-syenite pegmatite of the Isle of Rouma[159] off the coast of French Guinea also contains a large number of rare alkalic minerals.

Syenite pegmatites with a calcite phase have been described occurring at several localities, including central Ontario;[160] the Seiland area in Finmarken, Arctic Norway;[161] and the vicinity of Laacher See in the German Rhineland.[162] Of unusual interest is a combined calcite-fluorite-radioactive mineral phase in a complex syenite pegmatite at Wilberforce, Ontario, which is described by Spence and Carnochan[163] and Spence.[164] The pegmatite consists dominantly of feldspar with minor amounts of accessory minerals. Within the pegmatite are a number of cavities one of which is at least 150 feet long by 5 to 10 feet wide and is filled with massive fluorite and calcite. Crystals of apatite, hornblende, magnetite, and uraninite lie embedded within the fluorite-calcite filling. Well developed feldspar crystals line the cavity walls. This pegmatite has been exploited for its radioactive mineral content.

Ore phases in intermediate pegmatites are rare. McLaughlin[165]

[156] Brögger, W. C., *Op. cit.*

[157] Fersman, A. E., Ueber die Natur der Pegmatitbildungem: *Compt. Rend. Acad. Sci. Russie*, pp. 89–92, **1924.** (Abs. *Min. Abstr.*, **2**, p. 399.) Regular intergrowths of minerals in the Khibinsky and Lovozersky tundras: *Bull. Acad. Sci. Russie*, **17**, ser. 6, pp. 275–290, 1923. Mineral associations in the Khibinsky and Lovozersky tundras: *loc. cit.*, pp. 65–80.

[158] Landes, K. K., A paragenetic classification of the Magnet Cove minerals: *Am. Mineralogist*, **16**, pp. 313–326, 1931.

[159] Lacroix, A., Les pegmatites de la syénite sodalitique de l'ile Rouma: *Compt. Rend. Acad. Sci. Paris*, **192**, pp. 189–194, 1931. (Abs. *Min. Abstr.*, **4**, p. 497.)

[160] Adams, Frank D., and Barlow, Alfred E., *Op. cit.*, p. 158.

[161] Barth, Tom, Die Pegmatitgänge der kaledonischen Intrusivgesteine im Seilandgebiete: *Skrifter Norske Vidensk. Akad.*, p. 102, **1927.** (Reviewed by Knopf in *Amer. Jour. of Sci.*, Mar. **1928**, pp. 272–273.)

[162] Schuster, Ernst., Calcitführende Auswürflinge aus dem Laacher Seegebiet: *Neues Jahrb. Min., Beil.-Bd.*, **43**, pp. 295–318, 1919. (Abs. *Min. Abstr.*, **2**, p. 123.)

[163] Spence, Hugh S., and Carnochan, R. K. The Wilberforce radium occurrence: *Can. Min. and Mett., Bull.* **23**, pp. 649–688, 1930.

[164] Spence, Hugh S., The pegmatite minerals of Ontario and Quebec: *Amer. Mineralogist*, **15**, pp. 480–490, 1930.

[165] McLaughlin, D. H., Copper sulphides in syenite and pegmatite dikes: *Econ. Geol.*, **14**, pp. 403–410, 1919.

describes the occurrence of pneumotectic chalcopyrite and bornite in syenite pegmatite in Ferry County, Washington.

Basic pegmatites are relatively scarce, especially the complex types. A large amount of hydrothermal activity following the crystallization of a basic pegmatite magma would not be expected, for the water content of such magmas is probably low. Examples of basic pegmatites are: diorite pegmatites associated with the Adirondack anorthosite;[166] diorite and gabbro pegmatites at Szarvaskö, Hungary;[167] gabbro pegmatites containing plagioclase, augite, diallage, and olivene beneath the Duluth gabbro;[168] diabase pegmatite in Virginia;[169] platinum-bearing dunite pegmatites in South Africa;[170] the coarse labradorite masses in the Labrador anorthosite, and both gabbro and pyroxenite pegmatites in Western Australia.[171]

A probable example of complex basic pegmatites is the occurrence of phlogopite-bearing pyroxenite pegmatites in Ontario and Quebec. These are described by Spence[172] in his monograph on mica. The following statement appears in a later paper: "These pyroxenites . . . often contain large, irregular cavities lined with well-formed pyroxene crystals and carry a filling of calcite, in which are scattered large apatite and mica crystals . . ."[173]

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166 Miller, Wm. J., Pegmatite, silexite, and aplite of northern New York: *Jour. Geol.*, **27**, pp. 28–55, 1919.

167 Szentpétery, S. v., and Ernszt, K., Petrochemische Daten aus der Gegend von Szarvaskö: *Foldtani Közlöny, Budapest,* **58** (for 1928), pp. 216–222, 1929. (Abs. *Min. Abs.*, **4**, p. 401.)

168 Grout, F. F., The pegmatites of the Duluth gabbro: *Econ. Geol.*, **13**, pp. 185–197, 1918.

169 Shannon, E. V., The mineralogy and petrology of intrusive Triassic diabase at Goose Creek, Loudoun County, Virginia: *Proc. U. S. Nat. Mus.*, **66**, art. 2, 1924.

170 Vogt, J. H. L., *Op. cit.*, p. 53.

171 Simpson, E. S., Contributions to the mineralogy of Western Australia, Series 6 and 7: *Jour. Royal Soc. West Australia*, vol. **17**, 1930–1931, p. 144; vol. **18**, 1931–1932, p. 67.

172 Spence, H. S., Mica: *Can. Dept. of Mines,* no. **701**, p. 41, 1929.

173 Spence, Hugh S., and Carnochan, R. K., *Op. cit.*, p. 662.