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CRITERIA FOR DISTINGUISHING NORMAL GRANITES FROM METALLOGENETICALLY SPECIALIZED ONES

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The metallogenetic analysis of tin-bearing ore districts shows that granitoid rocks occurring within these districts as contrasted with other granitoides, are characterized by distinctive geological, tectonic, geochemical and petrographic criteria.

Usually these granites are named as «tin granites», «tin-specialized granites», «specialized granites» or «metallogenetically specialized granites» respectively. It may be assumed that between the concerning granitoidic intrusive complex and the associated rare-metal deposits (with Sn, Li, Rb, Cs, Be, Nb, Ta, W, Mo, F) exists not only a spatial but also a genetic relation.

There are possibly a number of geological, tectonic, geochemical and petrographical pecularities of the metallogenetically specialized granitoides which may be used as criteria for their recognition. Application of these criteria aims to the recognition of promising districts in relation to the existence of rare-metal deposits.

1. The metallogenetically specialized granites or granitoid intrusive complexes are distinguished by:

a) their confinement to the middle to late stages of an orogeny;

b) a pronounced sialic magmatism presumably of palingenetic origin;

c) a true intrusive character;

d) their affiliation to postkinematic polyphase intrusive complexes at a hypabyssal intrusion level;

e) their confinement to the apical stage of batholiths and their relatively strongly undulating morphology (stocks, ridges);

f) the specific contents of some main elements which deviate from those in normal granites:

SiO_2	73,38	±	1,39
TiO_2	0,16	±	0,10
Al_2O_3	13,97	±	1,07

Fe_2O_3	0,80	±	0,47
FeO	1,10	±	0,47
MnO	0,045	±	0,040
MgO	0,47	±	0,56
CaO	0,75	±	0,41
Na_2O	3,20	±	0,61
K_2O	4,69	±	0,68

Compared to normal granites, the specialized granites are characterized by higher contents of SiO_2 and K_2O and by lower contents of TiO_2, Fe_2O_3, MgO and CaO. Significant differences between both granite types occur with decreasing certainty in CaO, TiO_2 and MgO.

g) An increase of the contents of specific rare elements in comparison to normal granites (regional specialization). Proposed averages for some trace elements are:

fluorine	3700	±	1500	ppm
rubidium	580	±	200	ppm
lithium	400	±	200	ppm
tin	30	±	20	ppm
beryllium	13	±	6	ppm
tungsten	7	±	3	ppm
molybdenum	3,5	±	2	ppm

Compared to the granite averages, in the specialized granites further granitophile elements (B, Nb, Ta, Cs, U, Th, RE) are also enriched, whereas granitophobe elements (Ni, Cr, Co, V, Sr, Ba) are impoverished;

h) An assymetrical (log normal) regional distribution of the rare elements, characterized by a strong increase in the amount of granitophile elements from the core of the pluton towards the outer margin (zonal specialization);

i) A strong increase of granitophile elements from the older to the younger intrusive phases in the specialized intrusive complexes (temporal specialization);

j) A relatively high dispersion of the elements which participate in the specialization;

k) A certain mineralogical composition, which leads to their classification, according to petrographical criteria, as alaskite granites, leucogranites, aplite granites, two mica granites (syenogranites and alkalifeldspar granites in the sense of STRECKEISEN).

The proposed average mineral composition (in vol-%) is:

quartz	35	±	3
alkali feldspar	33	±	6
plagioclase	25	±	3
dark mica	3	±	1
light mica	3	±	1
accessories	1		

As carriers and concentrators of rare elements, all rock forming minerals must be considered, especially the accessories. Dark micas, for instance, play a particular role as carriers as well as concentrators:

l) by a special association of accessories of which cassiterite, topaz, fluorite, tourmaline as well as columbite-tantalite and beryl are the most important;

m) by a paragenetic sequence of crystalization for the rock-forming minerals which deviates from that in normal granites. Quartz appears as early crystallization product and dark mica as a late one. This is probably caused by the high contents of volatiles, particularly fluorine, in the melt;

n) by autometasomatic late-magmatic processes leading to microclinization, muscovitization and albitization. These processes represent the first stage of the formation of apogranites (in the sense of BEUS);

o) by post-magmatic metasomatism (greisenization) with the formation of rare element deposits.

2. The specialized granites or granitoid intrusive complexes can be distinguished by the sum of their characteristics mentioned above. Considering the chemical elements, one can state that the specialized granites show considerable deviatins from normal granites in their rare element content (Sn, Li, Be, Rb, F), but variations with regard to the minor elements (Ca, Mg, Ti), and only very slight insignificant deviations in the major elements (Si, Al, Fe, Na, K). It cannot be expected that with only of *one* characteristic or a *few* characteristics a granite can be predicted as being ore bearing. The detection of specialized granites, moreover, only states something about the ore-generating capability of the corresponding specialized melt but nothing about the real existence of ore deposits. For the formation of ore deposits further prerequisites (presence of ore-supplying and ore-concentrating structures) must be given.

3. It is possible to distinguish intermediate to acid magmatic rocks (adamellites) occurring in tin-bearing regions as precursors of specialized grani-

tes. Like the specialized granites they also may form intrusive complexes. Their geotectonic position and geological setting is the same as the specialized complexes. In some properties (contents of the elements, petrographical composition, association of the accessories) these precursours are entirely similar to normal granites. In other properties (increased contents of granitophile rare elements, like Sn, Li, Rb, Be) they are similar to the specialized granites. They have typically *low* fluorine content. The pre-enrichment of the granitophile rare elements is considered as an indication of heredity and as a precondition of the still greater accumulation in the subsequently fractionated specialized granites. Of great importance for the formation of specialized granites is a magmatic trend following the formation of the precursors which allows a high enrichment of the volatiles, especially of fluorine, to develop.

4. The use of the existence of specialization in granitoid rocks as the basis for the detections of ore deposits is, according to present knowledge, applicable only where there exists a rather close, direct relationship between ore accumulation and spatially related intrusive complexes. This is obviously valid for Sn, Li, Rb, Be, Nb, Ta. In the case of W and Mo it is probable, but for Cu, Pb and Zn, according to our present knowledge, improbable.

5. The cause of a geochemical-petrographical specialization is considered to be related to a certain pre-enrichment of the corresponding element in the magma and to specific conditions of its formation. Such specialized granites are intruded at a relatively high level in the earth's crust, and by the abundance of volatiles, especially fluorine. Special conditions of formation delay the accumulation of rare elements if processes of crystallization dispersion prevail, and stimulate them if processes of emanation concentration predominate. High contents of fluorine seem not only to stimulate the anomalous crystallization sequence and to stimulate the autometasomatic processes, but also seem to be a fundamental prerequisite for the migration of tin and other trace elements. It can be said that for the formation of tin deposits high contents of fluorine are even more important than high contents of tin.

6. Presumably differing geotectonical preconditions control the formation of specialized granitoids (normal, agpaitic, plumasitic). Furthermore, on a planetary scale since regional (continental) and temporal (evolutionary) peculiarities appear, it might be expected, that, in spite of similar development in principle, the specialized granitoids are rather variable. This must be taken into consideration in the evaluation of the ore-generating capability of granitoid magmas or rocks respectively.