**GLOSSARY OF MagmaChem TERMINOLOGY**

A/CNK: Abbreviation for an index that measures the aluminum content of an igneous rock relative to calcium, sodium, and potassium: expressed as molecular Al2O3/ (CaO + Na2O + K2O). Peraluminous (aluminum-rich) rocks display A/CNK > 1.00, while metaluminous (aluminum-poor) rocks display A/CNK < 1.00.

Adiabatic melting: A process of magma generation in which the lithostatic pressure being exerted upon protolith is reduced while its temperature remains constant, resulting in volume increase and melting point reduction. Lithostatic pressure is reduced under conditions of crustal extension, such as those typically found in rift settings, where melting of lower lithosphere or upper asthenosphere occurs mainly by adiabatic processes. Since volatiles are not introduced in appreciable quantities during adiabatic decompression, the resultant magma will be anhydrous, and will exhibit iron-enrichment during differentiation. Rocks crystallizing from this magma are commonly characterized as being tholeiitic. However, since protolith of any alkalinity or composition may be adiabatically melted, these rocks are more precisely classified according to their magma series affinity.

AFM ternary diagram: A ternary (triangular) petrologic diagram used to represent the relative concentrations in weight percent of K2O + Na2O (A, for alkalies), FeO\* (F, for total iron, calculated as 0.9(Fe2O3) + FeO), and MgO (M, for mafic minerals) found in igneous rocks. This diagram especially enhances the behavior of iron concentration over the course of crystallization of a magma.

Alkalinity: The K2O **+** Na2O content of an igneous rock, as expressed in weight percent. >alkalic: in broad terms, one of the alkaline magma series defined by Peacock based on the alkali-lime ratio. In the Magmachem classification system, the alkalic magma series is subdivided into two magma series based on the degree of silica saturation: quartz-alkalic is defined by K57.5 values between 3.8 and 4.5, KCa values between 57.5 and 56.0, and **KMg** values between 53.75 and 52.5, and is characterized by containing normative quartz and/or hypersthene; nepheline alkalic is defined by K57.5-v values between 4.5 and 7.5, KCa values between 56.0 and 53.5, and KMg values between 52.5 and 49.0, and is characterized by containing normative nepheline. defined by K57.5 values between 2.45 and 3.7. >alkaline: a petrochemical distinction of igneous rocks, broadly defined. In the MagmaChem classification system, alkaline is a superseries distinction defined by K57.5 values above 2.45, and Kea values below 65.5. Rocks with K57.5 values below 2.45 and KCa values above 65.5 are considered subalkaline.

Andean subduction: Subduction of oceanic lithosphere beneath continental lithosphere at angles of about 50 degrees. Magmas produced in this setting are typically metaluminous, hydrous, and non-iron-enriched.

A/NK: Abbreviation for an index based on the molecular ratio of aluminum to potassium plus sodium (mol. Al2O3/K2O + Na2O). A/NK < 1.00 indicates the rock is peralkaline.

Argillic-alteration: An alteration process by which plagioclase and amphibole are converted to kaolinite, montmorillinite, and allophane, while K-feldspar is not affected. Sodium is intensively leached, but not potassium. Argillic alteration is expressed by highly peraluminous A/CNK ratios. -alteration zone: a zone of alteration found in porphyry copper deposits gradationally outward from the phyllic alteration zone, and characterized by the presence of secondary quartz-kaolin-montmorillinite mineralization.

Asthenosphere: That layer of the earth which lies beneath the lithosphere (75 to 125 km below the surface) and above the mesosphere (1000 km below the surface). The upper 100 km of the asthenosphere includes the Low Velocity Zone. The asthenosphere is equivalent to the lower 2/3rds of the upper mantle in pre-plate tectonic terminology.

A-Type Subduction:

A-Granite:

Calc-Alkalic: One of the subalkaline magma series originally defined by Peacock based on the alkali-lime index. In the MagmaChem classification system it is defined by K57.5 va.lues between 1.15 and 2. 45, KCa values between 71.0 and 65,.5, KMg values between 65.0 and 58.5, and KNa-Ca (Peacock Index) values between 63 and 57.

Calc-Alkaline: One of two divisions of subalkaline rocks defined as being a magma series based on the lack of iron enrichment displayed during differentiation on an AFM diagram.

Calcic: One of the subalkaline magma series defined by Peacock based on the alkali-lime index. In the MagmaChem classification system it is defined by K57.5 values between 0. 2 and 1.15, KCa values above 71.0, and KMg values above 65.0

Comagmatic: Said of igneous rocks which are presumed to have differentiated from a common mafic parent, based on similarities in chemistry and mineralogy.

Cordilleran subduction: Subduction of oceanic lithosphere beneath continental lithosphere at anomalously low angles (less than 150). Magmas generated in this setting are generally peraluminous, hydrous, and non-iron-enriched, and produce two-mica granites that are loosely considered to be s-types.

Crust: The outermost layer of the earth lying beneath the atmosphere and oceans, and terminating at the Mohorovicic seismic discontinuity, beneath which lies the mantle. crust is the upper portion of the lithosphere in plate tectonic terminology. Oceanic crust ranges from 5 to 15 km thick, and continental crust ranges from 30 to 80 km thick.

Decretion: Regional scale tectonic erosion of material from the base of an overriding lithospheric plate during low-angle to flat (Cordilleran-type) subduction.

Differentiation, magmatic: The process by which a parental magma evolves into two or more magmas that are chemically distinct from one another, and from the parental magma. There are many mechanisms by which magmatic differentiation may occur, including crystal-liquid fractionation, liquid immiscibility, vapor transport, cumulate gravitational crystal settling, thermogravitational diffusion, and adiabatic decompression. In metaluminous, hydrous magma series produced in Andean-type subduction and in peraluminous magma series produced during continental­ collision, or low-angle to flat (Cordilleran-type) subduction settings, adiabatic decompression is MagmaChem's favored mechanism of differentiation. Differentiation index (D.I.): A petrologic classification technique developed by Thornton and Tuttle that quantifies the tendency of magmatic differentiation processes to enrich residual liquids in certain felsic minerals. D.I. is calculated by summing the following normative minerals: quartz (Q), orthoclase (Or), albite (Ab), nepheline (Ne), potassium metasilicate (Ks), and leucite (Le).

Epigenetic: Said of mineral deposits that form after the lithification of their enclosing host rocks.

Ferric-ferrous ratio: The ratio of wt.% Fe2O3/FeO, which loosely reflects the ratio of ferric (Fe3+) to ferrous (Fe2+) iron in an igneous rock. (Fe3+/Fe2+ is approximately 0. 9 {Fe2O3/FeO).) In the MagmaChem classification system the ferric-ferrous ratio is the main parameter used to distinguish mini-series.

Fugacity: In chemistry, the partial pressure that a non-ideally behaving gaseous component would have if it were to behave ideally. In geology, fugacity is very loosely equivalent to the availability of a particular gaseous component in a magma.

Harker variation diagram: A Cartesian (x-y) diagram that plots the concentration of one element or oxide against the concentration of silica (SiO2). This displays the variation behavior of the particular element or oxide with respect to the variation of silica.

Hydrous/anhydrous: A distinction that expresses the relative water content in magmas. Hydrous magmas contain 1.5 to 12% water and anhydrous magmas contain Oto 5 % water.

Hydrous melting: A process of magma generation achieved by the introduction of water and other volatile compounds into protolith, which causes the melting point of the protolith to be reduced while its temperature, pressure, and volume remain constant. Hydrous melting is common in Andean- and Cordilleran-type subduction zones, where volatiles are supplied to the portion of lower lithosphere or asthenosphere directly above the subduction zone by devolatilization of subducting oceanic crust. Crystallization of these magmas produces rocks exhibiting an iron-poor differentiation trend, which are commonly referred to as calc-alkaline.

Hypersthene normative: Said of an igneous rock for which it has been determined that the orthopyroxene hypersthene occurs in the normative calculation for that rock. This situation precludes the occurrence of normative nepheline in the rock, and indicates that the rock crystallized from a melt saturated in silica.

I-Granite: A type of granite produced by partial melting of igneous rocks ranging from gabbroic to granitic in composition. I-granites are metaluminous, and so may contain biotite, hornblende, or sphene as accessory minerals.

Ilmenite series: A series of granitic rocks that are characterized by the presence of a small amount of ilmenite, **and a** lack of magnetite. This situation presumably reflects crystallization conditions of low oxygen fugacity.

Indices: More than one index.

Iron-enrichment: The behavior of iron relative to magnesium in a suite of comagmatic igneous rocks, characterized by an overall increase in the FeO\*/MgO ratio with increasing silica, presumably reflecting iron enrichment during differentiation.

K57.5 index: A petrochemical index that expresses the relative potassium concentration in a suite of comagmatic igneous rocks. The index is the value of K20 at which Si02 **=** 57.5 wt.%, based on a trend line constructed from measured K20 concentrations on a Harker (K20/Si02) variation diagram.

KCa index: A numerical petrochemical index developed by MagmaChem, and defined as the value of silica at which the difference of wt.% (K20 - CaO) equals O. The KCa index is used to- distinguish magma series affinity.

Lithosphere: That layer of the earth which lies beneath the hydrosphere-atmosphere, and atop the asthenosphere. Normal lithosphere ranges from 75 to 125 km in thickness, and includes the crust and upper one-third of the mantle of pre-plate tectonic terminology.

Magnetite series: A series of granitic rocks characterized by the presence of both magnetite and ilmenite. This situation presumably reflects crystallization conditions of relatively high oxygen fugacity.

Magmachem "call": The characterization of the metallogeny of an ore deposit in terms of magma series affinity, and *is* applicable to ore deposits that are empirically and, by inference, genetically related to an identifiable igneous event.

Magma series: A suite of comagmatic igneous rocks that have evolved along a petrochemically distinct differentiation path from, and controlled by the composition of, a more mafic parental melt.

Magma Suite: A set of spatially and temporally related igneous rocks. To be a magma series, magma suites must meet the taxonomic petrochemical requirements of the magma series petrochemical classification. Thus, all magma series are magma suites but not vice versa.

Magma System: A specific rock type within a magma series characterized by a particular degree of differentiation as determined from the Thornton-Tuttle differentiation index.

Mantle: That layer of the earth 5 to 15 km beneath the top of the oceanic crust, and 30 to 80 km beneath the top of the continental crust, extending 2900 km down to the top of the core. The top of the mantle is defined at the Mohorovicic seismic discontinuity. The mantle includes the lower lithosphere, the asthenosphere, and the mesosphere of plate tectonic terminology.

Megachart: An informal term for MagmaChem's chart entitled Metallogeny, Magma Series, and Geotectonic Setting of Igneous Rocks". The chart displays the magma series chemical classification system and its relationships to petrology, ore deposits, and plate tectonics.

Megaseries: In the Magmachem classification system the most fundamental classification level, at which all igneous rocks are divided into peraluminous and metaluminous megaseries. Peralurninous rocks display A/CNK > 1.00, and metaluminous rocks display A/CNK < 1.00, but may produce differentiates with A/CNK to 1.10.

Melting: Those processes which convert solid rock (protolith) to liquid rock (magma). Melting processes fall into three main categories: thermal (introduction of heat), adiabatic (pressure reduction accompanied by volume expansion), and hydrous (lowering of melting point by introduction of volatiles). Certain process dominate.in particular geotectonic settings, e.g., hydrous melting is Characteristic of subduction settings, adiabatic melting is characteristic of extensional or rift settings, and thermal melting is characteristic of hot spot settings.

Metallogenesis: The process of formation of metalliferous mineral deposits.

Metallogenic province: A terrane or geographic area containing mineral deposits similar in metallic composition regardless of form, style, and geologic age.

Metallogeny: The characterization of an ore deposit, igneous suite, or magma series in terms of its metallic composition and concentrations.

Metaluminous: Said of an igneous rock in which molecular Al2O3/ (CaO + Na2O + K2O) is less than 1.00. Metaluminous rocks may not contain primary garnet, cordierite, muscovite, or andalusite because of their aluminum-deficiency.

Mineral deposit: An occurrence of an anomalous concentration of metal or mineral material in a given geologic environment. Mineral deposits may be components of broader mineral systems that consist of one or more genetically related mineral deposits.

Mineral district: An area containing economic or non-economic mineral systems.

Mineral system: An economic or non-economic occurrence of mineralization that is genetically related to a definable geologic process. In many cases the geologic process results from magmatism or magmatic activity for which the magma series affinity can be ascertained. The relationship between magma series affinity and the metallogenic nature of the resulting deposit is the basis for the MagmaChem classification system.

Mini-series: A logical level in the MagmaChem classification system which divides magma series into mini-series, based on the oxygen content of the magma as inferred from parameters such as ferric/ferrous ratio (determined from Fe2O3/FeO content).

Mining district: A geographic area of historic mining activity composed of one or more mineral systems.

Miyashiro diagram: is calculated It is used to enrichment in A variation diagram in which FeO\*/MgO (FeO\* as 0.9xFe2O3 + FeO) is plotted against silica. characterize the nature and degree of iron a differentiating magma.

Molecular ratio: The ratio of the various molecules in a particular compound to each other. The ratio is calculated from major element oxide analyses by dividing each major element oxide by its molecular weight.

Molecular weight: The sum of the atomic weights of a substance.

Nepheline normative: Said of an igneous rock for which it has been determined that the feldspathoid nepheline occurs in the normative calculation for that rock. This allows the inference that the melt from which the rock crystallized was undersaturated in silica: this condition precludes the occurrence of normative quartz or hypersthene in the rock.

Norm (normative composition): A hypothetical assemblage of water-free standard minerals that could occur in a p articular rock, based upon a recalculation of the chemical composition of that rock. This calculation is based on a complex sequence of arithmetic manipulations. The CIPW norm is commonly used in North America and Britain, while in Europe the Niggli molecular norm is preferred. The normative calculation emphasizes the degree of silica saturation in the rock, with the following results: silica-oversaturated rocks contain normative quartz and hypersthene; silica-saturated rocks contain normative hypersthene but not quartz; and silica-undersaturated rocks contain olivine and/or nepheline, but not hypersthene or quartz.

Ore deposit: A mineral deposit that can be mined for profit.

Orthomagmatic: Said of processes in which metal-bearing brines derived during final crystallization of hydrous magmas are responsible for the deposition of an ore deposit.

Oxidation: In chemistry, that part of an oxidation-reduction reaction in which electrons are lost from certain atoms, such that the charge of the atom becomes more positive. In geology, an important oxidation reaction occurs when H2O is added to mafic magma, such that predominantly ferrous iron (Fe2+) in magnetite and ilmenite will be oxidized to ferric iron. (Fe3+) to form hematite. -state: In chemistry, the charge an atom or cation would have if its bonding electrons were to be taken by a more electro-negative atom or radical that it is binding with.

Oxidized: Said of a substance that has combined with oxygen, or has changed from a lower to a higher oxidation state by the process of oxidation.

Paradigm: A great ordering enlightenment; an explanation that solves a set of problems in an exceptionally clear and satisfactory manner. Evolution and plate tectonics are the two greatest paradigms in natural science.

Paragenetic sequence: The chronological sequence in which a paragenetic assemblage of minerals has been deposited.

Paragenesis: **Any** association or assemblage of minerals which have formed at the same time, and have a common origin.

Partitioning:

Peacock Index: A numerical petrologic index used to determine the magma series character of an igneous suite. The Peacock index of a suite is that value of silica at which the trend lines of (K2O + Na2O) and Cao intersect, as plotted on a Harker variation diagram.

Peralkaline: Said of an igneous rock in which molecular (K20 + Na20) is greater than Al203 (i.e., **A/NK** > 1.00). Peralkaline rocks have normative aegirine and lack normative anorthite.

Peraluminous: Said of an igneous rock in which the molecular ratio of Al203 to the sum of Cao + Na20 + K20 (A/CNK) is greater than 1.00. Peraluminous rocks do not contain sphene or hornblende, but characteristically contain biotite, muscovite, garnet, and/or cordierite due to excess aluminum content. Peraluminous rocks more mafic than granodiorite is not known.

Perpotassic: Said of an igneous rock in which molecular ratio of Al203 to K20 is less than 1.0. Perpotassic rocks do not contain normative albite. Perpotassic behavior is mainly restricted to the ultra-alkalic and high-K ultra-alkalic magma series.

Petrographic province: A geographic area containing igneous rocks similar in chemical and minmeralogical composition regardless of style, form, and geologic age.

Phyllic-alteration: An alteration process by which feldspars, micas, and mafic minerals are converted into sericite and quartz, and is accompanied by leaching of sodium from the rock. This type of alteration is mineralogically characterized by a secondary mineral assemblage that includes the fine-grained white micas muscovite, hydromica, and phengite; plus pyrite, chlorite, and sphene, and is chemically characterized by depletion of sodium and calcium relative to original aluminum content and highly peraluminous A/CNK ratios. -alteration zone: a zone of alteration associated with porphyry copper deposits, and characterized by the presence of secondary quartz-sericite-pyrite mineralization.

Propylitic-alteration: An alteration process by which plagioclase, hornblende, and biotite are converted into epidote, chlorite, calcite, and montmorillinite. Alkali leaching is unimportant. -alteration zone: a zone of alteration associated with porphyry copper deposits that affects the country rock and extends 1 km beyond the copper ore zone. This zone is characterized by the presence of secondary epidote, calcite, and chlorite.

Protolith: Lithological material prior to its conversion to magma by an igneous process, or alteration by metamorphic or hydrothermal processes.

Quartz-normative: Said of an igneous rock for which it has been determined that quartz occurs in the normative calculation for that rock. It indicates that the melt from which the rock crystallized was oversaturated in silica.

Reduced: Said of a substance that has lost oxygen, or has changed to a lower oxidation state by the process of reduction.

Reduction: In chemistry, that part of an oxidation-reduction reaction in which electrons are gained by certain atoms, such that their charge becomes more negative. In geology, an important reduction reaction is caused by anaerobic bacteria, in which S6+ in the sulfate radical (SO4)2- is reduced to S2- as hydrogen sulfide (H2S).

S-granite: A type of granite produced by partial melting of pelitic sedimentary materials from which sodium has been removed by weathering. S-granites are generally peraluminous (A/CNK ratios greater than 1.10): biotite, muscovite, garnet, and/or cordierite: and contain more than 1% normative corundum. Chappell and White originally defined an S-granite as being a peraluminous granite in which K2O>Na2O, Sr<200 ppm, Fe2O3/FeO < 0.5, and which has associated Sn-W metallogeny. In the MagmaChem classification system these S-granites are categorized as peraluminous, alkali-calcic, reduced magma series. Today the term S-granite is more broadly applied to muscovite-bearing peraluminous granitoid rocks. This more general usage has been adopted by MagmaChem.

Solidification index: An index employed in petrologic classification schemes in which a numerical value is assigned to an igneous rock based on the following calculation: 100 x MgO / (MgO + FeO + Fe2O3 + Na2O + K2O). The value obtained numerically portrays the location the rock would have on an AFM diagram.

Spilitic alteration: An alteration process by which feldspar is converted into albite, and secondary chlorite, calcite, epidote, chalcedony, and prehnite occur as low temperature hydrous crystallization products. The process involves the circulation of seawater through basaltic rocks.

Switch: A set value which distinguishes one magma series group from another.

Syngenetic: Said of mineral deposits that form during lithifi­ cation of their enclosing host rocks.

Thermal melting: A process of magma generation by which the melting point of protolith is reached by raising its temperature while pressure remains constant. Production of magma is accompanied by an increase in volume. In oceanic island, or hot-spot geotectonic settings, thermal melting of protolith at or near "topographic bumps" along asthenoshperic layer boundaries may result from heat flow toward the "bump" from the underlying, hotter layer. Once the process *is* initiated, it may continue for a long time, as the hot-spot point source will continue to focus heat from the underlying layer (e.g., the 80+ Ma Hawaiian-Emperor hotspot seamount chain).

Tholeiitic: In standard petrologic nomenclature, one of two divisions of subalkaline igneous rocks defined as being a magma series based on an increase in iron content during differentiation, as displayed on an AFM diagram.

Total iron (FeO\*): The sum of FeO = 0.9(Fe2O3).

Variation diagram: A Cartesian (x-y) diagram on which data such as major-element oxide or trace element concentrations are plotted. Since both parameters normally are not constant, the concentration of one parameter will vary with respect to the concentration of the other parameter. (Also see Harker variation diagram).

Weight percent: In chemistry, the percentage that a particular component contributes to the weight of a compound that contains it.