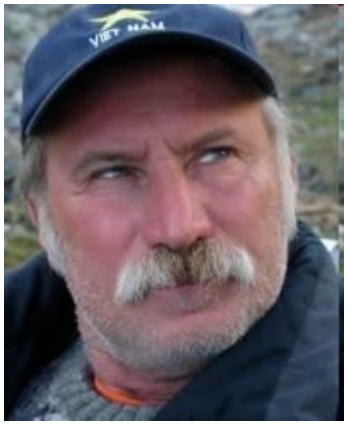
Novosibirsk State University
*THE REAL SCIENCE

IGNEOUS PETROLOGY: MAGMA GENERATION, DIFFERENTIATION AND ORE POTENTIAL



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Main research interests: mineralogical-petrographic, geochronological and geochemical investigations of layered ultramafic-mafic associations of Central and Southeast Asia. The regularities of the evolution and spatial distribution of ultramafic-mafic magmatism of large igneous provinces of Asia are investigated and the features of the formation of Cu-Ni –EPG mineralization are shown. The prospect of individual massifs and territories of Russia, Mongolia and Vietnam in relation to the primary and placer platinum mineralization has been substantiated.

Lecture 1. Magma Generation from Various Mantle Substrates

General patterns of partial melting of the asthenospheric and lithospheric mantle (composition of the substrate, host medium P-T-boundary conditions, fluid regime, abnormal P-T gradients and their interpretation in relation to plate and plume tectonics, degree of melting and its effect on the composition of primary mantle magmas, equilibrium, and dynamic models of magma formation). Features of magma generation in the subduction zone. Crystallization products from primary mantle magma and geodynamic models of their formation.

Lecture 2.

The origin of ophiolites as a reflection of tectonically superimposed upper mantle restites and mafic magmas genetically related to them (MORB-basalts and the genesis of N-, T-, E-type problems). The origin of komatiites. The origin of meimechites and alkaline picrites. The origin of marianites and boninites.

Lecture 3. Magma Generation from Various Crustal Substrates

General patterns of quartz-feldspar crustal substrate partial melting (degree of melting with "standard" temperature gradient in the earth's crust conditions, the problem of anomalous temperature gradients in the earth's crust associated with plume tectonics, equilibrium and dynamic models of granite formation). Primary crustal magma crystallization products and geodynamic models of their formation. Origin of primary crustal granitoids (TTG «gray gneisses"). Origin of autotonous and paraautotonous granites and ultrametamorphic zone granitoids. Origin of alumina-supersaturated (high-alumina) granites and their volcanic analogs, products of metasedimentary crustal substrate melting (S-granites). Origin of alumina-saturated (moderate-alumina) granites and their volcanic analogs, products of magmagenic crustal substrate melting (I-granites). Origin of alumina-undersaturated (low-alumina) granites and their volcanic analogs, products of metasomatically transformed crustal substrate melting (A-granites).

Lecture 4. The Concept of Magma Differentiation

History of the magma differentiation problem. N. Bowen's experiments and his differentiation series. Physico-chemical properties of magmatic melts and fractionation conditions. Analysis of the Stokes equation and limitations of crystallization differentiation. Relationship between layered intrusions and volcanic associations. Crystallization differentiation in lava lakes using Hawaii as an example. Layered intrusions formation time. Crystallization in sills and mathematical modeling of crystallization processes. The concept of parental and derivative magmas. Main factors of crystallization-gravitational differentiation in sills. The structure of differentiated sills using examples from the Siberian craton. Features of the upper and lower zones of sills quenching and their correspondence to the parent magma. Internal structure of differentiated sills. The concept of cumulus and intercumulus. Features of variations in the chemical and geochemical composition of rocks and rock-forming minerals. Sandwich Horizon. Reasons for the asymmetric sills structure Mathematical modeling of crystallization processes (Melts). The basic principles for the "Comagmat" (A.A. Ariskin) and Pluton (A.V. Lavrenchuk) programs for modeling the processes of crystallization-gravitational differentiation in sills and layered intrusions. Calculation of pseudo-liquidus mineral temperatures for a given melt composition. Calculation of the trajectory for changes in the composition of the melt and minerals in the process of equilibrium and fractional crystallization. Calculation of the composition of rocks and minerals during the formation of a layered intrusive massif within the framework of the convection-cumulative hypothesis. Calculation of the composition of the parental melt. Using the parental melt of MORB basalt to show how the sequence of mineral crystallization, their composition, petrochemical and geochemical features of cumulates, and residual melts change depending on the pressure and oxygen fugacity at which fractionation occurs. Limiting the possibility of differentiation of basalts to granites.

Lecture 5. Reasons for the Diversity of Igneous Rocks and Their Primary Factors

Physical and chemical properties of melts and magmas (temperature, viscosity, density, oxygen fugacity, fluid saturation). The concept of initial (parent) and derivative magmas. The reasons for the variety of igneous rock compositions. Partial melting and the role of substrates of different composition as the main factors in the diversity of primary magmas (for example, the crust-mantle boundary). Differentiation. Segregation. Fractional crystallization: in a moving stream of magma, gravitational fractionation of crystals, and filter pressing. The role of assimilation. The problem of mixing various magma compositions. Hybridization processes.

Lecture 6. Structure of Layered Intrusions

Marginal facies of layered intrusions and the problem of their formation. Layered series. Stratification principles and descriptions of layered series. Basic terms: micro- and macro-stratification, hidden stratification, uniform stratification, and phase stratification. Examples of the main types of layering (Skaergaard, Bushveld, Alaska intrusions). Features of bottom and top-layered series. Sandwich horizon. Signs of multiphase formation of layered intrusions. Layered intrusions of various geodynamic environments. Early Precambrian dunite-harzburgite-orthopyroxenite-gabbro plutons associated with large igneous provinces: Stillwater, Great Dyke, Monchegorsky and Pansky, Kivaka, Bushveld, and Chineisky. Composition features of parental magmas for these intrusions (high silicon contents with high Mg #). Ore content features of these massifs. Phanerozoic dunite-troctolite-gabbro and gabbro-dolerite intrusions associated with Phanerozoic LIPs (Yoko-Dovyren, Norilsk, Dzhanbaoshan, Kalatogke, and Skaergaard). Riphean plutons of autonomous anorthosites. Features of composition, age, geodynamic and petrogenetic models of their formation. Layering in ophiolite complex. Features of the structure, composition, and differentiation of Omani ophilites as an example of MORB type ophiolites. Dunite-troctolite-gabbro layering complex of Ural ophiolites (Kokpekty massif). The layering complex of Bayankhongor ophiolites as the websterite-anotrosite type. Dunite-wehlite-clinopyroxenite-gabbro layering ophiolite complex of back-arc basins using examples from Tuva, Khantayshiri and Daribi (Western Mongolia) Karashite massifs. Features of layered ophiolite complex with boninites (Khantayshiri, Dundzhugur, and Troodos). Island-arc dunite-troctolite-gabbro layered gabbroids and Ural-Alaska differentiated dunite-clinopyroxenite-gabbro intrusions. Gabbro-granite series problems. Gabbroid assemblages of accretion-collisional and strike-slip geodynamic settings.

Lecture 7. Ore Mineralization in Layered Intrusions and its Formation Mechanisms

Chromite mineralization in layered intrusions and mechanisms of its formation. Iron-titanium-vanadium mineralization in layered intrusions (Bushveld, Chiney, Kachkanar, and Khoshimgol massifs). Differences

between early and late magmatic formation of titanomagnetite ores. Saturation problems of basic melts with sulfur, sulfide-silicate liquation. Behavior of platinum group elements during melting, crystallization differentiation, and segregation. Formation models of disseminated and massive sulfide copper-nickel ores. Formation models of low-sulfide platinum reefs (UG2, Merensky in Bushveld, JM reef in Stillwater, Platrif in Skaergaard, etc.

Lecture 8. Differentiation of Granite Melts by the Shrinkage Convection Mechanism

Features of the multiphase granite massif: structures (main phase granites, phases of additional intrusions, and final phase). The concept of homodromy and polychrony. Petrochemical and geochemical signs of granite melt differentiation. Various geodynamic settings of granitoid batholiths. Features of the structure, mechanisms, and models of formation. Ore content of granitoid associations. Rare metal granites, ongonites, and elvans.

Lecture 9. Large Igneous Provinces: Elimination Criteria, Age Boards, LIP Formation Models, and Evolution

Age boundaries of plateau-basalts, dike belts, and layered intrusions. LIP time evolution. Relationship between crust uplift and rifting processes in LIPs. Criteria for allocation of LIP centers. Models of the formation of various large igneous provinces as a result of mantle-crustal interaction. LIP connection with biota mass extinctions. Magmatism and metallogeny in specific LIPs: Paleoproterozoic (2.7-1.85 billion years), Neopriterozoic (1.4-0.725 billion years), Phanerosoic (Emeyshan, Tarim, and Siberian), Early Precambrian magmatism and metallogeny (2.7-1.85 Ga) LIPs (with examples from Bushveld, the Kola-Karelian region, and Chinei). Evolution of magmatism and metallogeny in the Emeishan large igneous province, signs of uplift of the earth's crust and rifting, temporal and lateral zoning, mantle-crustal interaction. Evolution of magmatism and metallogeny in the Siberian large igneous province. Magmatism in the Maymecha-Kotuiskaya province, Norilsk region, and Priangarye. Features of basement magmatism in the West Siberian plate. The final stage of the Siberian LIP (lamproites, carbonatites, alkaline picrites, and kimberlites). Evolution of magmatism and metallogeny in the Tarim large igneous province. Problems of LIP isolation in folded belts, features of tectonics and mantle-crustal interaction, an investigation of weathering, transport, and depositional processes.

Lecture 10. LIPs and Metallogeny

Petrological and geochemical features of mantle melting conditions in central LIP zones. The reasons for the connection of large deposits of Cu-Ni PGE, Fe-Ti-V and low-sulfide platinum mineralization in the central LIP zones. Features of metallogeny during mantle-crustal interaction. Zoning of PGE distribution in Siberian traps LIP. The relationships between large Cu-

Ni-PGE, Cu-Mo, Au, and REE deposits with deep mantle plumes using the examples from the Siberian (250 Ma), Tarim (285 Ma), and Emeishan (260 Ma) LIPs. Demonstrating that Cu-Ni and Fe-Ti-V deposits with anomalously high contents of platinum metals are confined to the central LIP regions. These features are associated with high PGE contents in parental magmas associated with deep plumes. Cu-Mo and Au deposits are confined to the peripheral areas of LIPs.

Lecture 11. Petrological Models of Magmatic Series Formation in Various Geodynamic Settings

Oceanic ridge magmatism. Inland rift zone magmatism. Magmatism of hot spots and fields: oceanic islands, traps, and A-granites. Types of mantle sources (DM, EM-1, EM-II, HIMU, and DUPAL-anomalies) and their relationship with the isotopic-geochemical composition of basalts. Petrological models of the formation of MORB and OIB type basaltic melts. Magmatism continent – ocean transition zones: young and mature island arcs, back arc basins, transform fault, marginal continental volcano-plutonic belts, and rifts of active continental margins. Indicator of geochemical relationships in basalts of active continental margins and their relationship with magma generation processes in subduction zones. Anomalies of Ti, Nb, and Ta in the magmatic series of active continental margins and their interpretation. The role of pelagic and MORB components in magma generation during the subsidence of the oceanic lithosphere in subduction zones. Origin of active continental margin high-alumina and high-magnesium basaltic melts. Problems of the genesis of andesite magmas. Petrological models of the formation of granitoid batholiths on active continental margins. Collisional zone magmatism. The role of mantle melts in collisional tectogenesis.