МИНИСТЕРСТВО НАУКИ И ВЫСШЕГО ОБРАЗОВАНИЯ РОССИЙСКОЙ ФЕДЕРАЦИИ
НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ
ТОМСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ

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7th LARGE IGNEOUS PROVINCES CONFERENCE
SEPTEMBER 2-5, 2019
TOMSK, RUSSIA

25 YEARS RFBR

Laboratory of Geochronology and Geodynamics
Tomsk State University

LARGE IGNEOUS PROVINCES THROUGH EARTH HISTORY: MANTLE PLUMES, SUPERCONTINENTS, CLIMATE CHANGE, METALLOGENY AND OIL-GAS, PLANETARY ANALOGUES
(LIP – 2019)

Abstract volume of the 7 International Conference
Tomsk, Russia, 28 August – 8 September 2019

КРУПНЫЕ ИЗВЕРЖЕННЫЕ ПРОВИНЦИИ В ИСТОРИИ ЗЕМЛИ: МАНТИЙНЫЕ ПЛЮМЫ, СУПЕРКОНТИНЕНТЫ, КЛИМАТИЧЕСКИЕ ИЗМЕНЕНИЯ, МЕТАЛЛОГЕНИЯ, ФОРМИРОВАНИЕ НЕФТИ И ГАЗА, ПЛАНЕТЫ ЗЕМНОЙ ГРУППЫ (КИП – 2019)

Тезисы VII Международной конференции
Томск, Россия 28 августа – 8 сентября 2019

with the formation of lamproites of the Fansipan province. The youngest age (25 Ma) was obtained for amphibole gabbroids, the formation of which took place in shallower conditions, probably after exhumation. The basic magmatism of the ASRR zone ends with the introduction of gabbro-dolerite dikes. The presented materials testify to the manifestation of a mantle ultrabasic-basic magmatism synchronous with shear movements in the Shong-Khong zone, and thus substantially complement the known tectonic constructions.

Acknowledgements

This work was conducted as a government task of the Ministry of Education and Science of the Russian Federation

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LARGE IGNEOUS PROVINCES (LIPS) AND METALLOGENY; PUTTING LIP-RELATED MINERAL DEPOSITS INTO A LIP FRAMEWORK CONTEXT

Jowitt S. M.[1], Ernst R. E.[2,3]

[1]*Department of Geoscience, University of Nevada Las Vegas, Las Vegas, NV 89154-4010, USA.*
[2]*Department of Earth Sciences, Carleton University, Ottawa, Canada*
[3]*Faculty of Geology and Geography, Tomsk State University, Tomsk, Russia*

Keywords: *Large Igneous Provinces, metallogeny, mineralization, hydrothermal, economic geology*

Introduction

Large Igneous Province (LIP) events involve the transport of a significant amount of energy and metals from the Earth's mantle to the crust and are directly involved in (e.g. magmatic sulfide systems), drive (e.g. hydrothermal systems driven by the heat involved in LIP events) or otherwise causatively influence a variety of differing metallogenic systems (e.g. the weathering of LIP rocks to generate residual bauxite or laterite deposits; Ernst and Jowitt, 2013). These events can also directly affect the maturation of hydrocarbon source rocks and the formation of oil and gas reservoirs and are genetically related to the development of some important aquifer systems.

This presentation provides an overview of the key links between LIP events and the formation of mineral deposits, including those that form during metallogenic events that occur significantly after the formation of the LIP involved in this mineral deposit genesis. Combining these links with the development of a plumbing framework for LIPs (Ernst et al., in press) allows the development of targeting strategies focused on the sections of LIPs that are known to host or be associated with differing types of mineral deposits.

Links between LIP events and metallogeny

LIPs are genetically associated with a wide variety of different mineral deposit types, including magmatic sulfide Ni-Cu-platinum group element (PGE), iron oxide-copper-gold (IOCG), orogenic gold, Al-bauxites, and Ni-Co laterites, as well as water and hydrocarbon resources (Ernst and Jowitt, 2013). These associations can be distilled into five distinct types of relationship, with the caveat that these relationships may overlap both temporally and spatially:

(1) LIP magmas that directly generate mineralization, such as orthomagmatic Ni-Cu-PGE sulfides or Nb-Ta-REE and diamonds associated with LIP-related carbonatites and kimberlites, respectively.

(2) LIP magmas that provide energy, fluids, and/or metals for ore types such as hydrothermal volcanogenic massive sulfide (VMS) and iron oxide-copper-gold (IOCG) deposits.

(3) LIP rocks (particularly sills and dykes) that acted as barriers to fluid flow and/or as reaction zones that control mineralizing events (e.g. during the formation of some Au deposits), acted as structural traps within hydrocarbon systems, or formed impermeable barriers that controlled water flow and hence aquifer formation.

(4) Surficial effects, such as the weathering of LIP rocks to form Ni–Co laterites and Al bauxites from exposed LIP mafic-ultramafic rocks in tropical climates and residual Nb, Ta, and REE laterites from LIP-associated carbonatites; and

(5) Indirect links between LIPs and ore deposits, where LIP-related continental breakup generates distal compression and transpression in the plate tectonic circuit that can lead to the formation of orogeny-related deposits, such as orogenic Au mineralization.

LIP events also enable the reconstruction of Precambrian supercontinents and the tracing of areas of metallogenic and hydrocarbon endowment between presently separated but formerly contiguous crustal blocks. However, although knowledge of these links is useful in e.g. regional exploration targeting and can inform and direct more localized exploration, what is needed is a combination of knowledge of these relationships and their relative timing with information relating to the location of these mineral deposits within the LIP system. For example, PGE-dominated magmatic sulfide mineralization is generally (but not always) located within deep-seated layered intrusions within the LIP plumbing system, whereas magnetite-related hydrothermal vent complex mineralization is generally located in near-surface environments, reflecting the genetic processes that formed these types of mineral deposit. This linking of spatial and genetic knowledge will allow the identification of key areas within given LIP systems for mineral exploration.

Metallogeny in a LIP framework context

A recent paper by Ernst et al. (in press) outlined the plumbing system of LIPs and the various forms of igneous units that form during continental LIP events. These magmatic components include flood basalts and associated different types of giant mafic dyke swarms, mafic sill provinces, lower crustal magmatic underplates, mafic-ultramafic (M–UM) intrusions, associated silicic magmatism (mainly related to the melting of lower crustal material as a result of heating by M-UM magmas), and associated carbonatites and kimberlites. This research outlined a plumbing system framework for plume-related LIPs that included all of these components, enabling the tracking of magma batches and their geochemical evolution, the interpretation of deep crustal LIP-related geophysical signatures, and more. In addition, this model has implications for mineral exploration and the use of the five-fold classification outlined above. Several examples of this are outlined below.

Magmatic sulfide mineralization is the best-known type of mineral deposit associated with LIP events and involves the transfer of chalcophile elements from deep in the mantle to the crust by high degree partial melts (e.g. Jowitt et al., 2014). The S-saturation of these magmas generates immiscible magmatic sulfides that can be concentrated to form economic Ni-Cu-PGE mineral deposits. Combining knowledge of these processes with the plumbing systems of LIPs can enable the tracking of chalcophile element variations that provide evidence of mineralizing processes, enabling improved identification of areas for targeted mineral exploration (e.g. Ernst and Jowitt, 2013, 2017). These areas include staging M–UM chambers, key locations for differentiation, crustal contamination, and the potential generation of magmatic sulfides, as well as linked intrusions where magma dynamics can cause the segregation of denser magmatic sulfides from the less dense transporting magma.

Other magma chambers within LIP systems can differentiate in situ or may be the site of magma mixing as new batches of M-UM magma are added to the chamber. Both of these processes can lead to S-saturation as exemplified by the LIP-related Skaergaard and Bushveld intrusions, respectively. The in situ differentiation of magmas within these chambers can also form other types of mineralization, such as gabbroic Fe-Ti-V mineralized intrusions that, if exposed by erosion, can represent viable exploration targets.

The upper sections of LIP plumbing systems can also be associated with mineralization, as exemplified by sills that intrude sedimentary basins and are often associated with hydrothermal vent complexes. These complexes record the interaction of sill magmas with volatile-rich sedimentary rocks, producing zones of brecciation that reach the surface from depths of up to 9 km and are linked with both magnetite mineralization as well as hydrocarbon potential (e.g. Ernst and Jowitt, 2013).

This lecture will outline the key relationships and links between LIP events, the formation of LIP-related mineral resources, and the identification of key metallogenic locations within LIP systems, all of which can be used to enhance mineral exploration strategies for a range of LIP-related and hosted mineral resources.

Conclusions

LIP events are genetically associated with the formation of a wide range of mineral deposits both during and after the events themselves. These mineral deposits are located within different areas of LIPs depending on the geological processes that generate individual classes of deposit. Combining this knowledge with a newly developed plumbing framework for LIP systems will enable more focused targeting for LIP-related mineral deposits.

Acknowledgements

REE partially supported from Mega-Grant 14.Y26.31.0012 of the government of the Russian Federation, and Canadian grant NSERC-CRDPJ 523131-17

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