The Emperor's New Clothes: Looking Beyond to New Ways of Thinking about Uranium Deposits

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Summary

To enhance our success at new discoveries of uranium deposits, we need to develop new ways of looking at these deposits, including new technologies that expand our knowledge about how uranium deposits form and are preserved, as well as why they don't form.

Introduction

Uranium deposits appear throughout the geological cycle, from magmatic and fluid fractionation in the deep continental crust to precipitation at the surface (Fig. 1). Each type of occurrence has been studied to varying degrees, and as we accumulate more knowledge and move up the uranium learning curve, we also realize that there are many aspects about uranium deposits we do not understand. The last exploration boom saw the "re-discovery" of deposits, with few new discoveries, and none of these were very substantial--this despite the global effort and significant resources that were invested. One way to enhance our success at new discoveries is to develop new ways of looking at these deposits, including new technologies that expand our knowledge about how uranium deposits form and are preserved, and why they don't form where we think they should.

Theory and Results

Let us take the example of unconformity-related uranium deposits because very high-grade, large-tonnage U deposits have only been discovered in the vicinity of unconformities of Paleoproterozoic age, between redbed basins and basement complexes characterized by relatively high U contents, graphitic metapelites and ductile faults. Repeated brittle reactivations of the ductile structures were foci for fluid flow and ore deposition resulting in anomalous Li, Mo, U and clay alteration halos, at least in the case of the Athabasca Basin. Fluids that produced these deposits can produce significant alteration zones and the presence of reductants in the basement rocks such as graphite, and of alteration zones in the overlying sandstone are among the major indicators of an environment conducive to uranium enrichment. Exploration techniques that exploit these features include airborne and ground geophysics involving novel magnetotelluric and resistivity methods, surface geochemistry, biogeochemistry and clay typology. Although these methods have lead to new discoveries, the presence of a strong reductant and a significant alteration zone does not normally lead to the discovery of a uranium deposit. Thus, the success rate of drilling is relatively low, with only a few tenths of percent intersecting any sizable amount of uranium, but many intersecting apparently barren alteration systems. A major problem in present-day uranium exploration, regardless of the deposit type being sought, is recognizing the elements and features that are missing from the barren alteration systems compared to known uranium deposits. These barren systems are largely understudied, primarily because the direct economical interest in them is low, despite their likely importance in understanding the subtle but critical differences between mineralized and non-mineralized alteration systems. Subtle differences in sedimentology, diagenesis, structural effects on the paleohydrology of the system, and critical reactions are required for mineralization, but these factors are not yet predictive.

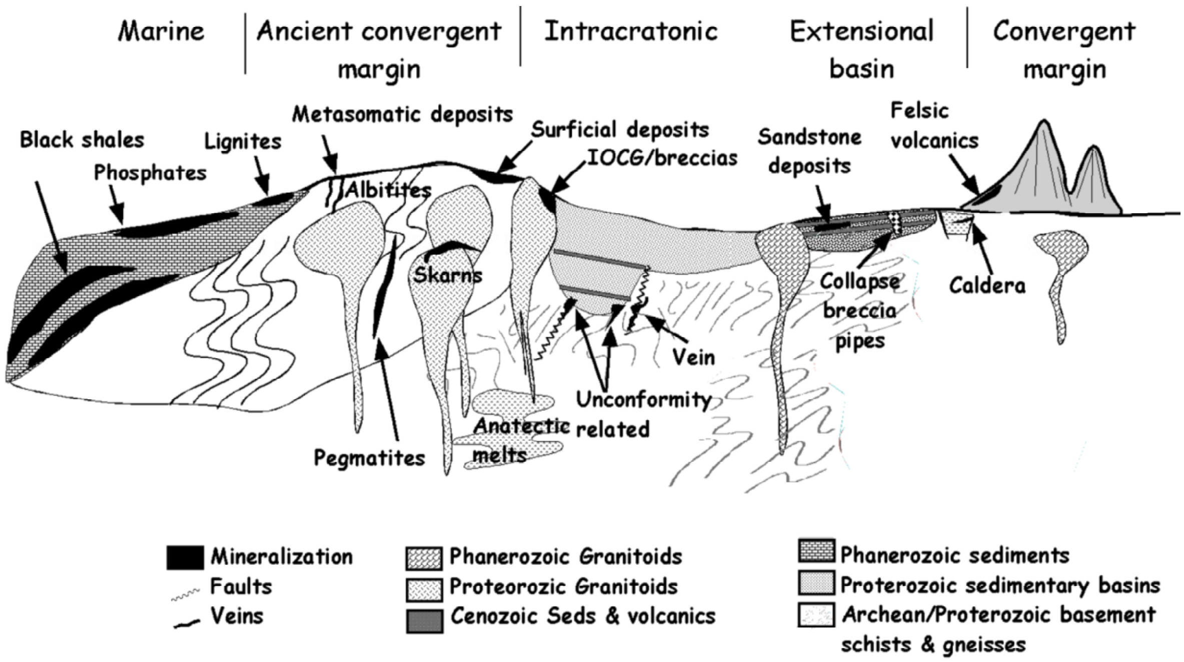

Figure 1. Various types of U deposits and their tectonic setting. After Kyser and Cuney (2009) Introduction. In: Cuney, M. and Kyser, K. *Recent and not-so-recent developments in uranium deposits and implications for exploration*. Mineralogical Association of Canada Short Course Series Volume 39, 1-14.

As we take a step back to get a better view of the deposits, new realizations and techniques are on the horizon to enhance our understanding of these deposits. One focus is on the precipitation mechanism, since the source of U in most environments is multifarious and always there, although starting with U-rich sources is an asset. Of concern is the effective trap for U, which normally involves temperature changes, fluid mixing and redox reactions. For the latter, graphite in the basement of unconformity-related deposits may be a poor reductant because it tends to be inert and therefore, must be transformed to an intermediate product that can reduce the U. Other redox systems may be effective at fixing U, including Fe^{2+}, S^{2-} and even Cr^{3+}, which open up new areas for exploration and give us additional tools to detect deposits. At high temperatures, magmatic degassing of alkaline systems may concentrate U in addition to differentiation processes, and at low temperatures, preservation of U deposits may be better than we previously thought. We should focus our thinking on the role of global tectonics in forming and modifying U deposits. Given that most magmas form, and most fluids move, as a result of specific tectonic events, the timing of deposit formation should be dependent on tectonics.

Among the new techniques are the use of isotopes to unravel fluid histories from deposition to later alteration and the role of the biosphere in forming deposits. The isotope systems being tested include those of U itself, Li, Mo, C, Sr and Pb, all of which reflect different, but overlapping, processes. Although the latter two elements have been used to understand U deposits, the use of Li, Mo, C and, particularly, U isotopes is a new way to analyze deposits and barren areas and to reveal the precise redox mechanism. The $^{238}U/^{235}U$ ratios of uranium minerals from volcanic-, metasomatic-, unconformity- and sandstone-related uranium showings and deposits worldwide indicate a total variation in $\delta^{238}U$ values of 0.15%, with the $^{238}U/^{235}U$ ratio varying as a function of the type of uranium deposit. $^{7}Li/^{6}Li$ ratios in muscovite and chlorite associated with uranium mineralizing events are distinct from background ratios, with the lowest values reflecting the beginning of hydrothermal alteration systems whereas the highest values are indicative of the terminal flow of hydrothermal fluids. The isotopic composition of C is being used to indicate microbial interactions with U deposits, which may be the process by which elements are mobilized out of the deposit and into the surrounding environment for us to use as vectors to or. The goal is to be able to use isotopes to reflect a definitive process that occurs in the deposit and not in barren systems, and then to relate these to something that is easier to measure, namely elemental concentrations.

Conclusions

Exploration for U deposits, as with any type of deposit, requires the integration of geology, geophysics and geochemistry, but must embrace new technologies and research results to be effective and competitive. Although “luck” and “serendipity” will always be factors, exploration must be more purposeful, especially as the need to find deposits under cover becomes more urgent. We will always have to drill to find deposits, but we should be learning from our mistakes and successes, and be thinking forward, not distracted by the “emperor’s new clothes”.

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