Dynamics of Uranium Ore Formation in the Basement and Frame of the Streltsovskaya Caldera

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Vienna, Austria 23–27 June 2014
Geographical location of the Transbaikalian Region and Krasnokamensk (Hongshi) Area

[Map showing the geographical location with marked cities and countries: Russia, China, Mongolia, and Chita, Krasnokamensk.]
GIS model of the Krasnokamensk Area
Satellite view of the Area with the main faults and caldera edge, and sites under consideration

Main Fault Zones: 1- East Uruulunguy, 2- South Argun, 3- Dalaynor-Gazimur
Main elements of ore-forming fluid-magmatic system (a) and location of U deposits in the basement of the Streltsovskaya caldera (b)
Discrimination diagram for granitoids of the Streltsovskaya caldera basement and frame

**NW Frame - Urtuy Massif (red dots), SE Frame – Bambakay Massif (blue dots), Basement (Antey U deposit) of the Caldera (green dots). MZ granitoids are not spread and geodynamic setting are not specified. Field boundaries taken from Pearce et al., 1984.**

Granites:
- syn-COLG - syn-collisional
- VAG - volcanic-arc
- WPG - within-plate
- ORG - ocean-ridge
Regional tectonomagmatic and mineral events

<table>
<thead>
<tr>
<th>Stage</th>
<th>Period</th>
<th>Pre-economic U ore “warm-up”</th>
<th>TTA</th>
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<td>800</td>
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<td>500</td>
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<td>200</td>
<td>100 Ma</td>
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### Periods and Events

- **Proterozoic Cycle**
- **Caledonian Cycle**
- **Variscan Cycle**
- **T3-J2 Inversion**

### Stage PR3-PZ1
- **a** - Granite gneiss - Zauruluguy Massif
- **b** - 809±27, 806±19*, 745±33*
- **c**
- **d**
- **e** - 770±35

### Stage PZ2-3
- **a** - Plagiogranites, gneissic granites, Q-diorites.
- **b** - Cores of Aruq and Kilchka Domes
- **c** - Gabbro, diorites, Gravitic diorites - Gazimur Complex
- **d** - P1 volcanism
- **e**

### Stage J2-3
- **a** - Granodiorites - Shakhtama (Sretenski) Complex
- **b** - Priargun-Turgin series
- **c** - Kutin series

### Ages
- **b** - 242±20
- **c** - 585±1.6-521±2
- **d** - 238±1-208±0.5
- **e** - 195±79

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*a* – igneous and volcano-sedimentary complexes, *b* - zircon (U-Pb), *c* - muscovite (Rb-Sr), *d* – biotite (Rb-Sr), *e* – uraninite (U-Pb). Ages defined by V.N. Golubev (IGEM RAS and CRPG) and *TU Bergakademie Freiberg. TTA – tectonothermal activation.
“Chemical” age of uranium oxides in the vicinity of the Streltsovskaya caldera (after Laverov et al., 2012)
SE-NW seismic profile along the main ore fields of the Argun (Erguna) Massif and Gazimure terrain (after Dukhovskiy et al., 1998)

Ore Fields: 1 – Krasnokamensk (U), 2 – Klichka (Pb-Zn), 3 – Mulino (Au, Pb-Zn)
Episode I: ~800 - 540 - 380 Ma
Fold core, AR-PR granite-gneissic cupola, localization of listric and steeply-dipping faults bounding protograbens, Caledonian granites

Limiting temperature of isotopic system stability:
420°C - uraninite, 340°C - muscovite, 270°C - biotite
Episode II: 380 – 230 Ma
Variscian granites and onset of protograben in pull-apart regime
due to P2-T1 (~ 250 Ma) tectonomagmatic events

Rerun of Rb-Sr system of biotite due to Antey’s granite formation?

U-Pb and Rb-Sr ages are close.
Probably there was not later thermal impact to granite more than 300°C
Episode III: 230 – 135 – 100 Ma
Completion of pull-apart graben, tectonic inversion (T3-J2), volcanism-caldera development (J3-K1), formation of flank sedimentary basins (K1)

In connection with Variscan granite or later?

Uraninite transformation 195±79 Ma

U ore formation 133-135 Ma
Q-Cb-Hym to Q-Fi-Cal
300-130°C
U-ore stage 215-190°C
Age probability plot of the Phanerozoic granitoids in NE China (after Wu et al., 2011)

Caldera U ores: 136 ± 3 Ma

Cretaceous A-type granites: anorogenic (rifting) setting – Kukulbeyskiy (Li-F) complex

T3-J1 A-type granites: postorogenic setting – Shakhtaminskiy complex (?)

Permian A-type granites: final stages of orogenezis – Undinskiy complex (caldera basement)
Uranium distribution patterns for variously deformed granitic rocks

T17a – wall rock of the Urtuy Massif, T17b – NE-SW blastomilonitic zone (ductile deformation), T4 – Meridional fault (brittle deformation), T20 – fracture network (Fe, Ti and Mn oxyhydroxides). Slices and Fission-Track Radiography - IGEM RAS, uranium content (CU) - ICP-MS (CRPG, Nancy).
Paleostress regimes and fluidflow dynamics: technique (a) and results (b)

a: Dynamics of fluid permeability of the fault zones is reconstructed using spatial distribution and orientation of Fluid Inclusion Planes (Lespinasse et al., 2005; Ustinov, Petrov, 2011) in connection with data on faulting regimes.

b: Four clusters of FIPs in quartz of the Antey deposit due to their orientation, salinity and temperature of homogenization (Petrov et al., 2013).
Stress-time dependence of fluid permeability for the fault zones: A – NE-SW, B – NNE-submeridional, C – NW-SE

Periods of stress accumulation (I) and relaxation (II) are accompanied by inflow of multiple-aged fluid portions committed to fluid inclusion generations (from 1 to 4) during various tectonomagmatic cycles (TC) and regional tectonothermal activation (TTA).
Main Fault Zones: 1- East Urulunguy, 2- South Argun, 3- Dalaynor-Gazimur

Satellite view of the Area with the main faults and caldera edge, and sites for further prospecting activity

“Hidden” part of Caldera
CONCLUSIONS and CHALLENGES

1. CALDERA GRANITIC FRAME: Urtuy and Bambakay Massifs
   • AR-PR 800 Ma (relics?) granite-gneiss and PZ1 520 Ma (Caledonian) granites
   • NE-SW main fluid conducting faults
   • Uraninite formation 770±35 Ma and transformation 195±79 Ma (U-Pb)

2. CALDERA BASEMENT U Deposits:
   • AR-PR 800 Ma (relics) granite-gneiss (Argun deposit)
   • PZ2 240 Ma (Variscian) granites (Antey deposit)
   • NNE-submeridional main fluid conducting faults
   • Hydromicatization 131-139 Ma
   • U (economic) ores formation 133-135 Ma

3. Long-term fluid circulation in the ore-forming fluid-magmatic system:
   • Chronology
   • Depth (source and PT conditions)
   • Pathways
   • Transport mechanisms
   • Stress-strain-temperature field evolution