Granite-related Hypothermal Uranium Mineralization in South China

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June 24, 2014
1. Classification of Uranium Deposits in China

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3. Tectonic Cycle to Uranium Mineralization

4. Hypothermal Uranium Mineralization

5. Discussion
1. Classification of U Deposits in China

IAEA 2013 new classification: 15 types with 36 subtypes

1) Intrusive
   2) Granite-related
      3) Polymetallic iron-oxide breccia complex (IOCG)
      4) Volcanic-related
      5) Metasomatite
      6) Metamorphite
      7) Proterozoic unconformity
      8) Collapse-breccia pipe
      9) Sandstone
      10) Paleo-quartz-pebble conglomerate
      11) Surficial
      12) Lignite-coal
      13) Carbonate
      14) Phosphate
      15) Black shale
1. Classification of U Deposits in China

On the basis of host rocks, the uranium deposits were traditionally classified into four major types:

1) Granite type & Granite-related (endogranite)
2) Volcanic rock type & Volcanic-related (structure-bound)
3) Sandstone type & Sandstone (roll-front/tabular)
4) Carbonaceous-siliceous-argillaceous rock type & Carbonate or black shale type
5) Other type

No typical Proterozoic unconformity and Paleo-quartz-pebble conglomerate type deposits up to now.

(New suggestion on classification- Zhang, 2012, Li, 2013)
Uranium resources

- granite type: 28.5%
- volcanic type: 21.2%
- sandstone type: 35.4%
- Carbonaceous-siliceous-pelitic rock type: 10.5%
- Other: 4.4%
According to geological setting and the spatial distribution of different type uranium deposits:

The metallogenic region subdivisions were previously divided into:

- **5 uranium provinces**
- **18 metallogenic regions / belts**

in 3 regional geological domains
2. Metallogenic Region Subdivisions for Uranium Deposits

*New subdivisions (BOG, CNNC, 2012):*

4 uranium metallogenic domains:
- a, Paleo-Asian
- b, Qin-Qi-Kun
- c, Marginal-Pacific
- d, Tethys

11 uranium provinces

49 metallogenic regions / belts

Most of the discovered U deposits located in Marginal-Pacific domains with the mineralization age of Mesozoic- Cenozoic.
New Metallogenic Region Subdivisions for U Deposits in China

(Zhang et al. 2012)
<table>
<thead>
<tr>
<th>Domain</th>
<th>No. of Province</th>
<th>Name of province</th>
<th>Region/ Belt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paleo-Asian</td>
<td>II-1</td>
<td>Aertai-Zhungeer</td>
<td>III-1 Aertai potential belt</td>
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<td></td>
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<td>III-2 Zhungeer potential region</td>
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<td>III-3 Xuemisitan potential belt</td>
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<td>III-4 Wurunguhe potential belt</td>
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<td></td>
<td>II-2</td>
<td>Tianshan</td>
<td>III-5 North Tianshan potential belt</td>
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<td>III-6 South Tianshan belt</td>
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<td>III-7 Yili basin region</td>
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<td>III-8 Tuha basin region</td>
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<td>II-3</td>
<td>Talimu</td>
<td>III-9 North Talimu belt</td>
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<td>III-10 South Talimu potential belt</td>
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<tr>
<td>Qin-Qi-Kun</td>
<td>II-4</td>
<td>Qinqi-Kunlun</td>
<td>III-11 West Kunlun potential belt</td>
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<td>III-12 Qimantage potential belt</td>
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<td>III-13 Talimu basin potential region</td>
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<td>III-14 Longshoushan-Qilianshan belt</td>
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<td>II-5</td>
<td>Qinling-Dabie</td>
<td>III-15 South Qinling belt</td>
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<td>III-16 North Qinling belt</td>
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<td>III-17 Jingzai belt</td>
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<td>II-6</td>
<td>Daxinganling</td>
<td>III-18 Erlian basin region</td>
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<td>III-19 Badanjilin-Bayinggebi region</td>
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<td>III-20 Eerguna-Manzhouli potential belt</td>
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<td>II-7</td>
<td>Jihei</td>
<td>III-21 Zalantun potential belt</td>
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<tr>
<td>Marginal-Pacific</td>
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<td>III-22 Songliao basin region</td>
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<td>III-23 Dunhua-Mishan potential belt</td>
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<td>III-24 Yichun potential belt</td>
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<tr>
<td>Domain</td>
<td>No. of Province</td>
<td>Name of Province</td>
<td>Region/ Belt</td>
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</tbody>
</table>
| Marginal-Pacific | II-8          | North China Craton     | III-25 East Liaoning belt  
III-26 Xincheng-Qinglong belt  
III-27 Guyuan-Hongshanzi belt  
III-28 Ordos basin region  
III-29 Chaoshui basin region  
III-30 South Margin of North China Craton belt |
|                | II-9          | Yangzi Craton          | III-31 Middle and lower reaches of Yangtze River belt  
III-32 Tianmushan belt  
III-33 Xiushui-ningguo belt  
**III-34 Middle Hunan belt**  
III-35 Xuefeng-Mutianling Belt  
III-36 Middle Guizhou-Northwest Hunan belt  
III-37 Damingshan belt  
III-38 Sichuang basin region  
III-39 Kham-Dian（West Sichuan-Yunnan）Axis potential belt（IOCG type?） |
|                | II-10         | South China            | III-40 Gang-Hong belt  
III-41 Wuyishan belt  
**III-42 Taoshan-Zhuguang belt**  
III-43 Chengzhou-Qingzhou belt  
III-44 Leming basin potential region |
| Tethys         | II-11         | Gangdisi-Sanjiang      | III-45 Tengchong region  
III-46 Linchang region  
III-47 Duchang potential belt  
III-48 Bange-Jialing potential belt  
III-49 Chuoqing-Nanmulin potential belt |
In South China uranium province of Marginal-Pacific domain

**Distributions of volcanic/ granite-related U deposits in SE China**

**V: volcanic-related**

**G: granite-related**

**A**: Marginal-Pacific metallogenic domain

**D**: Paleo-Asian metallogenic domain

**C**: Tethyan metallogenic domain

In South China uranium province of Marginal-Pacific domain
3. Tectonic Cycle to Uranium Mineralization

*In regional:*

*Mesozoic – Cenozoic* epoch is the most important mineralization age in China.

*In space:* 86% discovered ore deposits located in East China marginal-pacific domain.

*In time:* most of the ore deposits formed at the age of 180Ma to 80Ma (Yanshanian epoch)

“Large-scale metallogenesis age”

----- (Mao et al, 2005)
Granite-related and volcanic-related Uranium mineralization in China share the same characteristics in space & in time.

What is the relation of tectonic cycle in Mesozoic-Cenozoic to U mineralization?
3.1 Major tectonic-magmatic stages of Yanshanian epoch in SE China

In Ganhang belt:

Two tectonic-magmatic sub-cycles
Stage 1 and 2 of late Yanshanian epoch (145－100 Ma)
Stage 3 of late Yanshanian epoch (100－65 Ma)

In Taoshan-Zhuguang belt:

Four tectonic-magmatic sub-cycles
Stage 1 of early Yanshanian epoch (205－165 Ma)
Stage 2 of early Yanshanian epoch (165－145 Ma)
Stage 1 and 2 late of Yanshanian epoch (145－100 Ma)
Stage 3 of late Yanshanian epoch (100－65 Ma)
### 3.2 The relation of tectonic cycles to U mineralization in East China

<table>
<thead>
<tr>
<th>Tectonic Period</th>
<th>Age (Ma)</th>
<th>Major tectonic-magmatic activities</th>
<th>Geodynamic</th>
<th>Relation to U mineralization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Late Yanshanian epoch</strong></td>
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</tbody>
</table>
| Stage 3 | 100-65 (K₂) | 1. depression basins (Erlian Basin)  
2. basic and acidic dikes, calc alkaline series | NW-SE extension | 1. epithermal U mineralization  
2. favorable braided river sedimentary system after the tectonic inversion |
| | | 1. Tectonic inversion  
2. Unconformity between K₂ and K₁ | Near SN compression | Favorable near SN extension-ductile faults & fractures by NE left-lateral movement |
| | 125-110 (K₁) | 1. thick continental lithospheric thinning by extension in East China  
2. fault subsidence basin, basin and range tectonics  
3. bimodal volcanic rocks, shoshonite, I type and A type granites related to mantle-crust interaction | NW-SE extension | 1. hypothermal U mineralization related to porphyry?  
2. favorable calc alkaline volcanic-subvolcanic host rocks for U mineralization |
| | 145-125 (K₁) | 1. large scale K-rich calc alkaline volcanic-subvolcanic rocks in East China  
2. transition of compression tectonics to extension tectonic | Multi-direction convergent orogen of three tectonic domains | U-rich S type granites in South China as the favorable host rocks |
| **Early Yanshanian Epoch** | | | | |
| Stage 2 | 165-145 (J₃) | 1. multi-direction convergent orogen, crust lithospheric thickening  
2. large scale S type granites  
3. transition of near EW tectonics to NE tectonics  
4. large scale thrust belts and foreland basins | Multi-direction convergent orogen of three tectonic domains | |
| | | 1. J₁-J₂ depression basin  
2. J₁-J₂ A type granites and bimodal volcanic rocks in South China  
3. tectonic inversion in J₂₂ depression basin | Near SN extension | basin tectonic inversion yielded the favorable sedimentary sequences, such as J₂₂ formation in Erdos basin |
| | | 1. large scale continental block collage, unified Europe – Asia plate  
2. near EW orogen, folds in covering and the thrust tectonics  
3. S type granites of Indo-Chinese epoch  
4. foreland basins (Erdos basin, Sichuang basin) | Continental collision | U-rich S type granite of Indo-Chinese epoch in South China as the favorable host rocks |
| **Late Indo-Chinese Epoch** | | | | |
4. Hypothermal Uranium Mineralization

Two uranium metallogenic systems in SE China?

Epithermal metallogenic system

Epithermal mineralization

Hypothermal metallogenic system

Hypothermal mineralization
4.1 Characters of epithermal mineralization

Type of ores: vein type
Alteration: silicification, fluoritization
Uranium mineral: pichblende
Mineralization age: < 100Ma
Mineralization T: < 250°C
Gap (H/M): big
Mineralization mechanism: mixing of ancient meteoric water with underground circulation fluids

**Gap:** Time gap between host rock and mineralization
Example: Mianhuakeng Deposit in North Guangdong

Section of Mianhuakeng Deposit

* Endogranitic
* Structure – control
4.2 Granite-related hypothermal uranium mineralization

In contrast to the characteristics of typical granite-related epithermal uranium mineralization:

* middle to high temperature mineral assemblage and alterations
* disseminated/stockwork uranium ores in fissuration granite with extensive potassic alterations
* relatively older mineralization age with the superimposed reformation of late epithermal mineralization

Recognized by researchers:


Beresitization (pyritized phyllite) type

--- by Prof. Du in 2006, 2009
Example 1: Zhushanxia deposit in Xiazhuang U ore field

1, middle grain -porphyritic biotite granite;
2, fine grain muscovite granite;
3, potassic alteration granite
4, diabase
5, altered fissuration zone
6, silicification zone
7, ore body
Example 1: Zhushanxia deposit in Xiazhuang U ore field

* extensive potassic alteration with biotitization in ductile zone
* uraninite + scheelite, with tourmaline (U: 0.24-0.56%, W: 0.3%)
* age of uraninite: 146〜165.5Ma (Hu et al, 2003)

Thin section of ore photo: (-) x25
Lin et al. 2014

Example 2: Shituling deposit in Xiazhuang U ore field

1, middle grain -porphyritic biotite granite;  
2, fine grain two-mica granite;  
3, diabase  
4, ductile fracture zone  
5, fractured silicification zone  
6, ore body  
7, tunnel  
8, drilling hole
Example 2: Shituling Deposit in Xiazhuang U ore field

Micro-vein/disseminated Ore
(Du et al., 2006)

Age of host granite: $238 \pm 2.3$ Ma
Age of U mineralization:
130—138Ma
Mineralization temperature:
290-338°C

* extensive potassic aleration, chloritization and sericitization in fissuration granite

* uraninite, coffinite and pichblende in black chlorite and sericite micro-veins
mu: hydromuscovite of biotite
cal: calcite, ru: rutile
hem: hematite
uth: uranothorite (accessory mineral)
q: quartz, cof: coffinite
per: perthitic microcline porphyroclast

Original host rock:
biotite porphyritic monzogranite

(Du et al. 2006)
Example 3: Lanhe deposit in North Guangdong

* Endogranitic
* Structure – control
Potassic alteration granite host rock

Pichblend micro-vein and Stockwork in fracture zone
4.3 General characteristics of hypothermal U mineralization

Type of ore: disseminated/stockwork in fissuration rocks
Alterations: alkaline metasomatism (potassic alteration), beresitization
Uranium minerals: uraninite, coffinite
Mineralization age: \(>\ 100\text{Ma}\)
Mineralization T: \(>\ 250\ \text{°C}\)
Gap(H/M): small, might related to small porphyry?
Mineralization mechanism:
boiling/mixing of fluids with ore forming solution derived from deep.
5. Discussion

More and more evidence indicates that there are multi-stages uranium mineralization in many granite-related uranium deposits in south China.

The early stage mineralization shares the characters of hypothermal U mineralization and had close relations to alkaline alterations.
* Evidence indicates the mixing of ore forming solution derived from deep (upper mantle?).

* Mineralization mechanism dominated by boiling and mixing of ore forming solution.

* Uranium mineralization priority occurred in the areas with lithospheric extension in crust thickening geological setting.
5. Discussion

- Contract term to “epithermal U mineralization”, it’s not the typical intrusive high temperature mineralization.

  * Detail studies needed, such as the mineralization ages, alterations and fluid inclusion for hypothermal mineralization.

  * Relation of hypothermal mineralization to late epithermal uranium mineralization?

  * New target for future exploration?
Thank you!