Dating of the Dachang Superlarge Tin-polymetallic Deposit in Guangxi and Its Implication for the Genesis of the No. 100 Orebody

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Abstract The Dachang superlarge Sn-polymetallic deposit in Guangxi, China, is one of the largest tin deposit all over the world. However, this deposit has long been in debate as to its origin. One of the opinions is that the Dachang deposit was formed by replacement of hydrothermal solution originating from Yanshanian granites, and the other is that this deposit was formed by submarine exhalation in the Devonian. This paper presents some new isotopic geochronology data obtained with the $^{40}\text{Ar}^{39}\text{Ar}$ method for quartz and sanidine from massive ore in the No. 91 and No. 100 orebodies. Analytic results show that the No. 91 orebody was formed at 94.52±0.33 Ma (the plateau age obtained with the $^{40}\text{Ar}^{39}\text{Ar}$ method for quartz) or 91.4±2.9 Ma (the plateau age obtained with the $^{40}\text{Ar}^{39}\text{Ar}$ method for feldspar), while the No. 100 orebody was formed at 94.56±0.45 Ma (the plateau age obtained with the $^{40}\text{Ar}^{39}\text{Ar}$ method for quartz), suggesting that both the No. 91 and the No. 100 orebodies were formed at the Late Yanshanian instead of the Devonian. The No. 100 orebody might be formed by filling of ore materials into caves in Devonian reef limestone. Because the ore-bearing solution released its pressure and lowered its temperature suddenly in a cave environment, ore minerals were formed concentrically while water and other materials such as CO$_2$ evaporated quickly, resulting less alteration of host rocks.

Key words: superlarge Sn-polymetallic deposit, Guangxi, Dachang, geochronology, pressure release and evaporation

1 Introduction

The Dachang tin-polymetallic deposit, located in northwestern Guangxi (Fig. 1), is one of the largest tin-polymetallic deposits in China, and also in the world. Among the producing mines, the Dachang tin-polymetallic deposit is unique for its large scale, high grade, diversity of metals and elements, complexity of mineral assemblages, clarity of zonation, and the variety of ore mineralization. As to the origin of the ore deposit, it is still in debate. In general, there are at least three different opinions upon the origin of the Dachang tin-polymetallic deposit, composed mainly of three large orebodies (No. 91, No. 92 and No. 100), which are the largest ones in the deposit. The first opinion argues that the Dachang deposit is an epigenetic metasomatic-infilling deposit and related to Yanshanian granitoids originally (Chen, 1964, 1965; Zhang et al., 1982; Chen et al., 1985; Zhang et al., 1987; Fu et al., 1991), the second opinion considers that the deposit is a syngenetic exhalative-sedimentary one formed in the Devonian and has no relation to granitoids (Cai and Zhang, 1983; Han et al., 1997), and the third opinion regards the Dachang deposit to be an poly-genetic deposit with a long history of ore forming and multiple sources of ore materials (Tu, 1984).

The authors have studied the characteristics and the origin of the Dachang deposit for more than 40 years, and published several papers and books (Chen et al., 1985, 1993, 1996). In these publications, the authors think that the main orebodies (the No. 91 and the No. 92 bedded orebodies) are metasomatic deposits formed by magmatic hydrothermal solutions originating from Yanshanian granitoids. By using the K-Ar method, the authors obtained an age of 138.6 Ma for fresh fine-grained granite, 117.9 Ma for K-feldspar alterative rocks formed at the earliest stage of mineralization, 90.9 Ma for illite filling in caves within the orebody (Chen et al., 1993) and 93.98 Ma for bedded metasomatic granitoids in the Lamo area (Wang, 1992). Therefore, the mineralization took place from 138.6 Ma to 90.9 Ma. In order to further constrain the ages of the main orebodies, the authors applied the $^{40}\text{Ar}^{39}\text{Ar}$ method to determine the age of quartz and sanidine within the Nos. 91 and 100 orebodies and publish new data in this paper.
2 Geological Setting and Sample Description

General features and the geological setting of the Dachang tin mine have been introduced in many research results (Chen et al., 1985, 1993, 1996). In short, the Dachang tin-polymetal deposit is composed of a series of veins and some stratiform orebodies, among which the No. 91 orebody hosted within banded limestones, the No. 92 one within siliceous shales and the No. 100 one within coral limestone are the most important ones. All of them are being mined at present, which has provided an opportunity for underground investigate and sample collection. Clear underground evidence shows that the No. 91 stratiform ore bed was formed due to metasomatism of ore-bearing solutions along bedding structures (Fig. 2), the No. 92 ore bed was composed of a lot of lens-like massive sulfide ores formed as calcareous nodules within siliceous shales were replaced (Fig. 3), and the No. 100 orebody is a superlarge infilling and metasomatic one hosted within reefs in sharp contact with the host limestone (Fig. 4). The features of the Nos. 91 and 92 orebodies have been discussed by many geologists (Chen et al., 1988, 1993; Xu et al., 1988; Ye et al., 1988; Lattanzi, 1989; Fu et al., 1991, 1993; Wang and Chen, 1996), but the No. 100 orebody is poorly discussed. The No. 100 orebody is also composed mainly of cassiterite-massive sulfide ores with an average content of up to 62.58% for sulfide, up to 20.39% for sulfosalt, up to 2.43% for cassiterite, and only 14.6% for gangue minerals.
Fig. 2. Metasomatic ores in the No. 91 orebody (at the 455-m level in the Tongkeng area).
The host rock is banded limestone; the width of the ore bed is about 50 cm.

Fig. 3. Metasomatic ore in the No. 92 orebody (at the 455-m level in the Tongkeng area).
The host rock is siliceous shales; the white part is calcareous nodule.

Fig. 4. No. 100 orebody in the Dachang mine.
Picture taken upwards with the bottom about 1 m wide. The upper left part (black color) is worked-out area of massive ores; the lower right part (gray color) is coral reef limestone; the central part (dark color) is cassiterite massive sulfide ores.

(Zhang, 1999). The average metal contents of ores are as fellows: Sn=1.79%, Pb=5.21%, Zn=10.10%, Sb=4.80%, As=7.38%, Ag=156.9g/t and S=28.62% (Wu et al., 1998). The major ore minerals are cassiterite, jamesonite, marmatite, pyrrhotite, pyrite and arsenopyrite.

The samples used in this study were collected from different ore types. Sadenine (405-26-2, Fig. 5) was collected from banded cassiterite-sulfide ore of the No. 91 orebody on line 26 at the 405-m level in the Tengkeng area, quartz (DC455-91Q) was from the cassiterite massive-sulfide ore of the No. 91 orebody on line 10 at the 455-m level in the Changpo area, and the quartz in the No. 100 orebody from the Gaofeng area. The two quartz samples were dated by the $^{40}$Ar-$^{39}$Ar heating method on minerals, while the sadenine was dated by the laser $^{40}$Ar-$^{39}$Ar method on polished thin sections.

3 Geochronological Study

Laser $^{40}$Ar-$^{39}$Ar dating was performed at the Isotopic Center of the Ministry of Land and Resources. A 0.5 mm

![Microscopy photo of sanidine (sample No. 405-26-2) and its Raman spectrum.](image)

Raman spectrum analysis is finished by Mr. Rong at the Raman Lab of the Institute of Geology, CAGS. The Renishaw Raman Database of Inorganic Materials is used, with the hit peaks at 513.25, 159.37, 282.87, 472.87 shift (cm$^{-1}$) indicating a typical Raman spectrum of sanidine instead of adularia (no hit peak at 159 shift cm$^{-1}$).
thick and 100 mm² large section was cut from a piece of banded tin ore, which was collected from the No. 91 orebody at the No. 26 section at the 405-m level in the Tongkeng area. After double-side polishing, this thin section was washed repeatedly by the ultrasonic wave in distilled water. After the cleaning, the polished section was put into an oven for surface drying. Then, it was concealed together with known-age standard samples in an aluminum foil capsule and irradiated by neutron in the H8 channel of a nuclear reactor. Neutron flux during irradiation was monitored using the biotite standard ZBH-25, which has an age of 132.7 Ma. The irradiation time was 3570 min, and the integral neutron flux was about 1.3×10¹⁸ n/cm². A CW-type Nd: YAG laser producer was used for sample fusion with lasers, and the entire process of seeking for a micro-area for in-situ fusion was monitored and observed by a micro-video monitor system. Argon isotopes were measured using a MM1200B mass spectrometer made by the VG company in England and a 17-grade Be-Cu electron amplifier. The age error is given as 1σ. A detailed description of the analytical procedure similar to that used in this study is given in Chen et al. (1994, 2002). The results are given in Table 1 and Fig. 4, indicating that the isochron ⁴⁰Ar/³⁹Ar age of sanidine is 91.4±2.9 Ma, with the ⁴⁰Ar/³⁹Ar value equal to 294±38.

Quartz separated from cassiterite massive sulfide ore from the No. 91 orebody at the 455-m level in the Changpo area was dated by the ⁴⁰Ar/³⁹Ar technique. The detailed analytical process can be referred to Sang et al. (1994). The results are listed in Table 2 and Figs. 7 and 8, yielding a spectrum plateau age of 94.52±0.33 Ma, an isochron age of 95.37±0.45 Ma, and an inverse isochron age of 94.89±0.16 Ma. This result is in agreement with the age of sanidine (isochron age 91.4±2.9 Ma) (Fig. 6).

The quartz sample separated from cassiterite massive sulfide ore from the No. 100 orebody was also dated by the ⁴⁰Ar/³⁹Ar technique, resulting in a spectrum plateau age of 94.56±0.45 Ma, an isochron age of 93.45±1.22 Ma, and an inverse isochron age of 93.29±0.16 Ma (Table 3, Figs. 9 and 10). Thus, the No. 100 orebody was formed at the same stage as the No. 91 orebody.

### Table 1: Analytic ⁴⁰Ar/³⁹Ar data for sanidine (405-26-2) from the Dachang tin deposit in Guangxi

<table>
<thead>
<tr>
<th>Spot</th>
<th>⁴⁰Ar/³⁹Ar</th>
<th>⁴⁰Ar/³⁹Ar</th>
<th>⁴⁰Ar/³⁹Ar</th>
<th>⁴⁰Ar/³⁹Ar</th>
<th>Age (Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.79746</td>
<td>0.004391</td>
<td>0.001073</td>
<td>6.49529</td>
<td>91.6±1.1</td>
</tr>
<tr>
<td>2</td>
<td>7.91017</td>
<td>0.005111</td>
<td>0.000921</td>
<td>6.39529</td>
<td>90.3±1.2</td>
</tr>
<tr>
<td>3</td>
<td>8.36012</td>
<td>0.0061256</td>
<td>0.001881</td>
<td>6.54530</td>
<td>92.3±1.2</td>
</tr>
<tr>
<td>4</td>
<td>8.40549</td>
<td>0.006513</td>
<td>0.001530</td>
<td>6.44531</td>
<td>91.0±1.3</td>
</tr>
<tr>
<td>5</td>
<td>7.95273</td>
<td>0.0048485</td>
<td>0.010941</td>
<td>6.51605</td>
<td>91.9±1.2</td>
</tr>
</tbody>
</table>

Analyzed by Chen Wen. J=0.008023. Isochron =91.4±2.9 Ma; ⁴⁰Ar/³⁹Ar = 294±38; MSWD=0.83.

4 Discussion and Conclusions

The above new ⁴⁰Ar/³⁹Ar dates on sanidine and quartz from the Nos. 91 and 100 orebodies in the Dachang tin-polymetal deposit provide new constraints on the time of ore formation. The quartz from the No. 91 orebody gives a ⁴⁰Ar/³⁹Ar plateau age of 94.52±0.33 Ma, accordant with its isochron age (95.37±0.45 Ma) and inverse isochron age (94.89±0.16 Ma). This result can be confirmed by the laser ⁴⁰Ar/³⁹Ar isochron age (91.4±2.9 Ma) on sanidine from the No. 91 orebody and by the K-Ar age of illite filled in roughs of the same orebody, suggesting that the No. 91 orebody was formed at the Yanshanian stage instead of the Devonian stage through exhalative sedimentation.

As to the origin of the No. 100 orebody, there are some different opinions all the while because no isotopic data have been obtained before this study. For example, some authors think the massive ore was deposited synchronously with the Devonian coral reef (Zeng et al., 1982), while some others consider that it is a hydrothermal deposit formed at the same time as the No. 91 orebody or the No. 92 orebody (Chen et al., 1993). Based on the ⁴⁰Ar/³⁹Ar plateau age of quartz, 94.56±0.45 Ma (isochron age of 93.45±1.22 Ma, inverse isochron age of 93.29±0.16 Ma), this study proves that the No. 100 orebody was formed at the Yanshanian stage. These ages from the No. 100 orebody are consistent with the ⁴⁰Ar/³⁹Ar ages of quartz and sanidine from the No. 91 orebody, and contemporary with the bedded granitoid metasomatic rocks in Lamo (93.98 Ma obtained with the K-Ar method) (Wang, 1992).

![Fig. 6. ⁴⁰Ar/³⁹Ar isochron age of sanidine (405-26-2) from the Dachang tin deposit.](image)
Table 2 Analytic $^{40}$Ar/$^{39}$Ar data for quartz (DC455-91Q) from the No.91 orebody, Dachang mine, Guangxi

<table>
<thead>
<tr>
<th>Stage</th>
<th>Temperature (°C)</th>
<th>$^{40}$Ar/$^{39}$Ar$_{in}$</th>
<th>$^{40}$Ar/$^{39}$Ar$_{in}$</th>
<th>$^{40}$Ar/$^{39}$Ar$_{in}$</th>
<th>$^{40}$Ar/$^{39}$Ar$_{in}$</th>
<th>$^{40}$Ar/$^{39}$Ar$_{in}$</th>
<th>$^{39}$Ar (%), Age (Ma) ±10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>400</td>
<td>36.478</td>
<td>0.0901</td>
<td>2.1564</td>
<td>0.76056</td>
<td>10.16 ± 0.055</td>
<td>10.0 ± 145.78 ± 7.92</td>
</tr>
<tr>
<td>2</td>
<td>480</td>
<td>21.688</td>
<td>0.0519</td>
<td>1.7895</td>
<td>0.34545</td>
<td>6.545 ± 0.024</td>
<td>21.8 ± 95.21 ± 2.55</td>
</tr>
<tr>
<td>3</td>
<td>560</td>
<td>27.244</td>
<td>0.0714</td>
<td>2.6283</td>
<td>0.51428</td>
<td>6.453 ± 0.037</td>
<td>13.9 ± 93.89 ± 3.57</td>
</tr>
<tr>
<td>4</td>
<td>640</td>
<td>32.305</td>
<td>0.0888</td>
<td>2.9270</td>
<td>0.67222</td>
<td>6.413 ± 0.048</td>
<td>10.2 ± 93.32 ± 4.57</td>
</tr>
<tr>
<td>5</td>
<td>720</td>
<td>42.074</td>
<td>0.12222</td>
<td>4.0361</td>
<td>0.87047</td>
<td>6.481 ± 0.063</td>
<td>7.66 ± 94.28 ± 5.92</td>
</tr>
<tr>
<td>6</td>
<td>800</td>
<td>48.954</td>
<td>0.14545</td>
<td>3.9300</td>
<td>0.91363</td>
<td>6.521 ± 0.066</td>
<td>6.24 ± 94.85 ± 6.25</td>
</tr>
<tr>
<td>7</td>
<td>950</td>
<td>51.923</td>
<td>0.14615</td>
<td>3.5678</td>
<td>0.92692</td>
<td>9.261 ± 0.0675</td>
<td>7.38 ± 133.27 ± 8.81</td>
</tr>
<tr>
<td>8</td>
<td>1100</td>
<td>40.895</td>
<td>0.10447</td>
<td>3.0916</td>
<td>0.69552</td>
<td>10.44 ± 0.050</td>
<td>9.51 ± 149.55 ± 7.45</td>
</tr>
<tr>
<td>9</td>
<td>1200</td>
<td>50.727</td>
<td>0.13090</td>
<td>3.3404</td>
<td>0.70181</td>
<td>12.52 ± 0.050</td>
<td>7.80 ± 177.95 ± 8.87</td>
</tr>
<tr>
<td>10</td>
<td>1300</td>
<td>68.817</td>
<td>0.18817</td>
<td>4.0189</td>
<td>0.88172</td>
<td>13.84 ± 0.064</td>
<td>5.27 ± 195.7 ± 12.11</td>
</tr>
</tbody>
</table>

Analysed by Sang Haiqing and Wang Yinglan. Sample weight = 0.2386g, J = 0.008278.

In short, the No. 91 orebody of the Dachang superlarge tin-polymetallic deposit was formed by magmatic hydrothermal replacement along beddings in the late Yanshanian and originally related to the Yanshanian granites. It is not a Devonian SEDEX-type massive deposit.

The origin of the No. 100 orebody is unique. Based on the investigation and the above geochronological discussion, this paper deduces that the No. 100 orebody might be formed by infilling of super-critical fluids in a paleo-karst cave. When the super-critical ore-bearing fluids flew into a possible paleo-karst cave, ore minerals would precipitate quickly when pressure was suddenly released and temperature lowered down. This mechanism can explain the feature of less alteration of the host rocks and the massive nature of the ore in the No. 100 orebody (Fig. 4).

The paleo-karst cave is probably an original oil trap formed within the coral reef. The oil trap might have been destroyed by the intrusion of the Yanshanian granites to result in remnant of bitumen (Zhang, 1999). The host rock of the No. 100 orebody is reef limestone, which is easy to be metamorphosed by hydrothermal solutions. However, the host rock of the No. 100 orebody has not been altered obviously, indicating a significantly different feature from the No. 91 orebody or the No. 92 orebody. This is also different from general hydrothermal deposits. Even typical exhalative-sedimentary deposits are accompanied by strong alteration, especially in footwall, suggesting that the No. 100 orebody might have been formed by an untraditional ore-forming process. However, as viewed from nanometer-

![Fig. 7. $^{40}$Ar-$^{39}$Ar spectrum of quartz (DC455-91Q) from the No. 91 orebody.](image)

![Fig. 8. $^{40}$Ar-$^{39}$Ar isochron age of quartz (DC455-91Q) from the No. 91 orebody.](image)
Table 3 Analytic $^{40}$Ar/$^{39}$Ar data of quartz (DC100Q) from the No. 100 Orebody

<table>
<thead>
<tr>
<th>Stage</th>
<th>Temperature (°C)</th>
<th>($^{40}$Ar/$^{39}$Ar)$_{initial}$</th>
<th>($^{38}$Ar/$^{39}$Ar)$_{initial}$</th>
<th>($^{39}$Ar/$^{39}$Ar)$_{initial}$</th>
<th>($^{37}$Ar/$^{39}$Ar)$_{initial}$</th>
<th>($^{39}$Ar/$^{39}$Ar)$_n$</th>
<th>($^{40}$Ar/$^{39}$Ar)$_n$</th>
<th>$\pm \sigma$</th>
<th>$^{39}$Ar$\lambda$ (%)</th>
<th>Age (Ma) ± 1σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>400</td>
<td>18.120</td>
<td>0.0300</td>
<td>1.912</td>
<td>0.17518</td>
<td>9.415 ± 0.012</td>
<td>28.6</td>
<td>135.41 ± 2.23</td>
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<td></td>
</tr>
<tr>
<td>2</td>
<td>480</td>
<td>24.493</td>
<td>0.06164</td>
<td>2.5001</td>
<td>0.34657</td>
<td>6.557 ± 0.024</td>
<td>15.7</td>
<td>95.37 ± 2.56</td>
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<td></td>
</tr>
<tr>
<td>3</td>
<td>560</td>
<td>26.300</td>
<td>0.0687</td>
<td>1.8468</td>
<td>0.43750</td>
<td>6.426 ± 0.031</td>
<td>10.3</td>
<td>93.51 ± 3.07</td>
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</tr>
<tr>
<td>4</td>
<td>660</td>
<td>27.636</td>
<td>0.07272</td>
<td>2.6168</td>
<td>0.43090</td>
<td>6.455 ± 0.030</td>
<td>11.8</td>
<td>93.92 ± 3.04</td>
<td></td>
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</tr>
<tr>
<td>5</td>
<td>760</td>
<td>37.785</td>
<td>0.10714</td>
<td>3.6875</td>
<td>0.67142</td>
<td>6.586 ± 0.048</td>
<td>6.02</td>
<td>95.77 ± 4.68</td>
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<tr>
<td>6</td>
<td>880</td>
<td>37.647</td>
<td>0.10294</td>
<td>3.5275</td>
<td>0.72058</td>
<td>7.676 ± 0.052</td>
<td>7.31</td>
<td>111.15 ± 5.79</td>
<td></td>
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</tr>
<tr>
<td>7</td>
<td>1000</td>
<td>37.631</td>
<td>0.0947</td>
<td>3.4307</td>
<td>0.57368</td>
<td>10.06 ± 0.041</td>
<td>8.17</td>
<td>144.33 ± 5.59</td>
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<td></td>
</tr>
<tr>
<td>8</td>
<td>1150</td>
<td>47.758</td>
<td>0.12413</td>
<td>3.7761</td>
<td>0.63103</td>
<td>11.57 ± 0.045</td>
<td>6.23</td>
<td>165.09 ± 7.46</td>
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<tr>
<td>9</td>
<td>1300</td>
<td>53.773</td>
<td>0.14339</td>
<td>3.7781</td>
<td>0.66792</td>
<td>11.92 ± 0.048</td>
<td>5.70</td>
<td>169.90 ± 8.09</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analyzed by Sang Haiqing and Wang Yinglan. Sample weight = 0.2634 g, J=0.008278.

Fig. 9. $^{40}$Ar/$^{39}$Ar spectrum of quartz (DC100Q) from the No. 100 orebody.

scale mineralization of super-critical fluids, it is acceptable that highly concentration of ore materials in free space (such as caves, open fissures) will be the result of evaporation of the ore-bearing fluids after sudden release of pressure. As vapor components such as H$_2$O and CO$_2$ evaporated and disappeared along fissures, ore materials could not be transported continuously but deposited at the bottom of caves to form massive ore or was filled in the fissures to form veinlets. This may explain that the No. 100 orebody has a great size but poor alteration of its host rock (Fig. 4). Of course, this is only one possible explanation. If it is true, such a mechanism of hydrothermal mineralization, i.e. "evaporation after sudden pressure release", can be applied to interpreting the origin of a large number of very rich massive ore deposits in Yunnan, such as the Laochang and Huize Pb-Zn deposits.

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Fig. 10. $^{40}$Ar/$^{39}$Ar isochron age of quartz (DC100Q) from the No. 100 orebody.
References


