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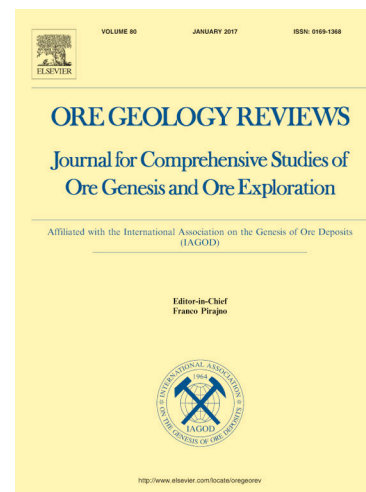
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**Spatial-temporal heterogeneity of magma emplacement process and its constraints on localization of associated orebody: A case study in the Shizishan orefield of the Tongling Ore Cluster, east China**

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## Abstract

We present a study on the Dongguashan quartz diorite stock which is the largest Early Cretaceous intrusion associated with skarn-porphyry polymetallic ore deposit in the Tongling Ore Cluster, Middle-Lower Yangtze Metallogenic Belt in East China. The Dongguashan quartz diorite show massive texture without obvious foliation, and intrusive contact was locally observed inside of the stock. The anisotropy of magnetic susceptibility (AMS) results of the stock show two distinct groups. The Group I (G-I) is dominated by NE-SW-striking magnetic foliation with variably oriented magnetic lineation. The Group II (G-II) that intruded into G-I is characterized by steep NW-SE-striking magnetic foliation and lineation, which are parallel to the vein-like orebody developed in the stock. The 3D geometrical modelling of the stock displays a triangular shape in plan-view with an eastward bulge and irregular stock boundary in the eastern side and the contact surface is steeper in the west than that in the east, denoting that the stock was constructed with an eastward magma accretion trend. Furthermore, the Dongguashan quartz diorite has a wide range of composition and geochronological data, suggesting a multiple magma pulses emplacement model. Accordingly, we propose that the Dongguashan stock was constructed by at least two stages magma pulses. The earlier stage magma pulses intruded along the NE-SW-striking pre-emplacement structures in the country rock and partly intruded into the lithological and mechanical discontinuous interfaces which yielded the stratabound skarn orebody. The eastward magma accretion produced a highly deformed and longer heated country rock on the eastern side of the stock, favoring the orebody development along the eastern stock-country rock contact interface. The late-stage magma pulse and the parallelism among the trend of magnetic foliation of G-II, extensional

structure and vein-like orebody suggest that the vein-type orebodies may controlled by both magma emplacement and regional tectonics.

**Keywords:** Dongguashan quartz diorite stock; Emplacement mechanism; AMS; Skarn-porphyry deposit; Tongling Ore Cluster

## 1 **1. Introduction**

2 Study of orebody localization is a key topic for the comprehensive  
3 understanding of epithermal metallogenic systems and is indispensable for more  
4 efficient exploration of hidden deposits. Nevertheless, orebody localization is a  
5 complex geological process that has been contested for decades due to the non-linear  
6 relationship among ore-controlling factors and the development of orebodies  
7 (Reynolds, 1958; Candela, 1992; Heinrich et al., 1996; Zhao et al., 2010; Liu et al.,  
8 2011; Sun and Liu, 2014). Previous geochemical and geochronological studies have  
9 revealed that magma intrusions, which determine the type and period of ore-forming  
10 process, were the essential ore-controlling factor (e.g., Eugster, 1985; Candela, 1992;  
11 Hedenquist and Lowenstern, 1994; Thompson et al., 1999; Hua et al., 2005; Mao et  
12 al., 2008, 2011; Sillitoe, 2010; Chen et al., 2012). However, the orebody localization  
13 is strongly controlled by the physical and geological conditions of the magma  
14 emplacement process, for example, magma ascent rate, emplacement depth, accretion  
15 pattern, temperature-pressure and strain field around the intrusion (e.g., Chesley et al.,  
16 1993; Duuring and Hagemann, 2001; Candela et al., 2005; Vigneresse, 2006, 2007;  
17 Eldursi et al., 2009; Holwell et al., 2014; Chen and Nabelek, 2017; Schöpa et al.,  
18 2017). Moreover, the geometries of pluton and pluton-country rock contact were also  
19 considered as important ore-controlling factors (Romeo et al., 2008; Liu et al., 2011,  
20 2014; Chicharro et al., 2015; Cao et al., 2020). Hence, the reconstruction of the  
21 magma emplacement process and 3D geometry of plutons is crucial for understanding  
22 the mechanism of orebody localization.

23 Anisotropy of magnetic susceptibility (AMS) is a successful method to reveal  
24 the magma emplacement process, as the pattern of magnetic fabric can reflect the  
25 magma flow direction, magma accretion and regional tectonic setting (e.g., Hrouda,  
26 1982; Ernst and Baragar, 1992; Rochette et al., 1992; Bouchez, 1997). In addition,  
27 with the development of computational modelling methods, the pluton geometry can  
28 be well defined by geophysical and borehole data (e.g., Améglio et al., 1997; Romeo  
29 et al., 2008; Liu et al., 2012; Lü et al., 2013; Sun and Liu, 2014; Wei et al., 2014).  
30 However, the application of AMS is usually impeded by limited surface exposures of  
31 the pluton, and the pluton geometry remains unclear due to the multi-use  
32 interpretation of geophysical data.

33 The Shizishan orefield is a representative skarn-porphyry ore deposit that is  
34 related to the Late Mesozoic intrusion and located at the center of the Tongling Ore  
35 Cluster, Middle-Lower Yangtze Metallogenic Belt, East China (rectangle inset in Figs.  
36 1 and 2). In this study, we chose the Dongguashan quartz diorite stock as our research  
37 target (Fig. 3) as it is the largest ore-forming intrusion in the Shizishan orefield.  
38 Furthermore, the Dongguashan quartz diorite stock has been previously well studied  
39 in geochemistry, geochronology and geophysics (Xu et al., 2005, 2008, 2010; Deng et  
40 al., 2006; Xie et al., 2012; Guo et al., 2013; Wang et al., 2015; Cao et al., 2016; Liu et  
41 al., 2018). However, the localization mechanism of these randomly developed  
42 skarn-porphyry orebodies around the stock is still ambiguous. The Dongguashan  
43 quartz diorite stock has been highly explored, and mining shafts and platforms have  
44 been constructed from the surface to -850 m in the depth, so that the AMS sampling

45 can cover the deep part of the Dongguashan quartz diorite stock. Moreover, with help  
46 of the intensive drilling projects in this area, the geometry of the stock and its related  
47 orebodies can be also reliably constructed. Therefore, through the field observation,  
48 AMS measurement, 3D geometry modeling and geochemical analysis of the stock, we  
49 acquired the distribution of magnetic fabric inside the stock, 3D geometry of the stock,  
50 as well as the variation of geochemical composition. Accordingly, we deciphered the  
51 development of the Dongguashan quartz diorite stock and the constraints on  
52 associated orebodies. Our study can help to guide the deep prospecting in the  
53 Middle-Lower Yangtze Metallogenic Belt and has implications that bear on other  
54 large-scaled intrusions.

## 55 **2. Geological background**

### 56 *2.1. Regional geological setting*

57 The Middle-Lower Yangtze Metallogenic Belt (Fig. 1a and b) is one of the most  
58 important Cu-Au-polymetallic belts in China, and in the world as well. It is a typical  
59 skarn-porphyry deposit belt related to Late Mesozoic intrusions developed in an  
60 intracontinental setting (Chang et al., 1991; Pan and Dong, 1999; Mao et al., 2011;  
61 Zhou et al., 2015). Hundreds of studies on these intrusions and their influences on the  
62 related skarn ore deposit had been done in the Middle-Lower Yangtze Metallogenic  
63 Belt, for examples, the geochronological, geochemical and petrological characteristics  
64 of the intrusions (e.g., Wang et al., 2004; Xie et al., 2009, 2017; Zhang et al., 2010;  
65 Yang et al., 2011; Yang and Lee, 2011; Wu et al., 2013), the origin of the  
66 hydrothermal fluid (e.g., Zhou et al., 2000, 2007; Lai et al., 2007; Gu et al., 2011; Cao



67 et al., 2012; Li et al., 2019; Liu et al., 2019), and the geodynamic setting and related  
68 implications for metallogeny (e.g., Deng et al., 2011; Mao et al., 2011; Shi et al., 2013;  
69 Lü et al., 2015).

70 The Tongling Ore Cluster (TOC; rectangle inset in Figs. 1b and 2) is located in  
71 the center of the Middle-Lower Yangtze Metallogenic Belt, where Early Cretaceous  
72 dioritic intrusions are widely developed and often associated with skarn-porphyry  
73 Cu-Au ore deposits (Fig. 1b). The TOC consists of the Tongguanshan, Shizishan,  
74 Xinqiao, Fenghuangshan and Shatanjiao orefields (Xie et al., 2017; Fig. 2). The  
75 stratigraphy of the TOC includes Lower Silurian to Upper Devonian siltstone,  
76 quartz-sandstone and silty shale, Middle Carboniferous to Early Triassic limestone,  
77 siliceous shale, calcareous shale and dolomite, and Late Mesozoic to Tertiary  
78 dolomitic limestone, clay shale, volcanic rocks, and continental clastic rocks (Zhai et  
79 al., 1992; Xu and Zhou, 2001). Structurally, the TOC is characterized by  
80 NE-SW-striking upright folds and high-angle NW- or SE- directed thrusts, and  
81 subordinate NNE-, NNW- and NW-striking brittle faults (Fig. 2; Chang et al., 1991;  
82 Tang et al., 1998). This structural pattern is considered to be an inherited structure that  
83 represents repeated NW-SE directed compressional regional tectonic setting. In  
84 particular, this includes the Middle Triassic intracontinental subduction of South  
85 China Block under the North China Craton (Lin et al., 1985; Zhao and Coe, 1987;  
86 Mao et al., 2011), and the southwestward subduction of the Izanagi plate under the  
87 east Eurasian plate since the Late Jurassic (Sun et al., 2007; Li et al., 2011). Moreover,  
88 the NE-SW-striking Early Cretaceous Luzong and Ningwu volcanic basins and

89 widespread Early Cretaceous intrusions and volcanism in the TOC suggest a  
90 predominantly extensional regional tectonic setting in the Early Cretaceous period  
91 (Deng et al., 2011).

## 92 **2.2. The Dongguashan stock**

93 Several Early Cretaceous intrusions are exposed in the Shizishan orefield (Fig.  
94 3), including the Dongguashan quartz diorite ( $138.4 \pm 1.7$  Ma; Wu et al., 2013), the  
95 Baimangshan pyroxene monzodiorite ( $139.9 \pm 1.9$  Ma; Guo et al., 2013), the  
96 Jiguanshi pyroxene-quartz monzodiorite ( $139.8 \pm 0.8$  Ma; Wu et al., 2008), and the  
97 Hucun granodiorite ( $140 \pm 2.6$  Ma; Xu et al., 2008). The Dongguashan quartz diorite  
98 belongs to metaluminous and high-K, calc-alkaline-series granite (delineated by white  
99 dash line in Fig. 3; Wu et al., 2010; Liu et al., 2018). Previous geobarometric studies  
100 on the contemporary Cretaceous intrusions in this area and geophysical investigations  
101 indicate that the Dongguashan quartz diorite stock was emplaced at the brittle crust  
102 depth (ca. 4-6 km; Du et al., 2004). The Dongguashan quartz diorite stock intruded in  
103 the hinge and eastern limb of the NE-trending Qingshanjiao anticline, which is  
104 considered as the major ore-controlling structure in the Shizishan orefield (Lu et al.,  
105 2003; Xu et al., 2005; Lü et al., 2013; Liu et al., 2014). Country rocks exposed on the  
106 surface are Middle to Lower Triassic limestone, argillaceous limestone and argillite,  
107 which were folded by the Middle to Late Triassic intracontinental orogenic event (Liu  
108 et al., 2014).

## 109 **2.3. Ore deposit**

110 With at least 10 exploited ore deposits and copper and gold reserves of more

111 than 1.5 Mt and 20 t, respectively (Xu et al., 2014), the Shizishan orefield is  
112 economically the most important Cu-Au district in the TOC. Especially the proven  
113 copper and gold reserves of the Dongguashan ore deposit are 0.98 Mt at 1.01% and 29  
114 t at 0.26 g/t, respectively (Liu et al., 2014, 2018). According to previous studies, there  
115 are three major ore localization zones around the Dongguashan stock, i.e. the  
116 Dongguashan, Datuanshan and Huashupo ores.

### 117 **3. Field observation and sampling**

118 The Dongguashan quartz diorite stock is not well exposed on the surface (Fig.  
119 3), and fresh quartz diorite outcrops were revealed only by the ore exploration. The  
120 Dongguashan stock mainly consists of medium to fine grained quartz diorite (Fig. 4a  
121 and b) and porphyritic quartz diorite occurs locally along the stock-country rock  
122 contact (Fig. 4c). The Dongguashan quartz diorite usually displays a massive texture  
123 without macroscopic foliation, but oriented hornblende grains with sub-horizontal and  
124 outward dipping plunge are locally observed in the contact zone (Fig. 4b).  
125 Metamorphosed country rock xenoliths are observed in the stock margin (Fig. 4d and  
126 e), which resemble the “exploding xenoliths” texture observed in the shallow level  
127 intrusions (Clark et al., 1998; de Saint-Blanquat et al., 2001). Moreover, the  
128 disharmonic folding of limestone strata (Fig. 4f) can be observed, suggesting the  
129 existence of decollement sliding in the country rocks.

130 The orebody developed around the Dongguashan quartz diorite stock is  
131 characterized by stratiform (Fig. 5a), massive (Fig. 5b), veinlet and vein-like textures  
132 (Fig. 5c and d). The major sulfides are chalcopyrite, pyrite, magnetite, pyrrhotite, and

133 the major gangue minerals are calcite and dolomite. Furthermore, our field  
134 investigation found widely developed extension related structures. For example, (1)  
135 the large-scale fracture zone developed in the stock with occurrence of  $120^{\circ}/66^{\circ}\text{SW}$   
136 (Fig. 5b), (2) the conjugated vein-type chalcopyrite ore dipping to SW and NE (ca. 0.5  
137 to 2 cm in width; Fig. 5c and e), and (3) widely developed southwest dipping calcite  
138 veins in the stock and its country rocks (Fig. 5d and f).

139 According to the architecture and layout of the mine shaft and platforms in the  
140 study area, we have chosen seven mine platforms for AMS sampling, i.e. -390 m,  
141 -460 m, -580 m, -670 m, -730 m, -790 m and -850 m. A total of 41 AMS sampling  
142 sites have been collected at different depths from -390m to -850m, which are evenly  
143 distributed along the accessible mining channels with an interval of ca. 100 m. Due to  
144 the limited resolution of the GPS signal in the mining channels and short distances  
145 between different sites, the locations of AMS sampling are presented on the plan-view  
146 of the stock. The AMS samples were collected with a portable gasoline drill and  
147 oriented using a magnetic compass. The collected core samples were cut into standard  
148 cylindrical specimens, i.e. 2.2 cm in height and 2.5 cm in diameter, for AMS  
149 measurements. Detailed sampling information is listed in Table 1.

150 Concurrently, representative massive fresh quartz diorite samples were collected  
151 from the -670 m platform, which is the largest section of the Dongguashan stock  
152 revealed by current mining projects, for geochemical analysis in order to investigate  
153 the horizontal variation of composition inside the stock. The locations of these  
154 samples are the same as the AMS sample at this platform.

## 155 **4. Analytical methods**

### 156 **4.1. Anisotropy of Magnetic Susceptibility (AMS)**

157 The magnetic susceptibility ( $K$ ) is defined as the ratio of the induced  
 158 magnetization ( $M$ ) to the applied field ( $H$ ), while the intensity of magnetization is  
 159 usually nonuniform due to the preferred orientation of minerals in the rock (Hrouda,  
 160 1982; Tarling and Hrouda, 1993), which is named as the Anisotropy of the Magnetic  
 161 Susceptibility (AMS). The AMS is a second-order tensor of the magnetic  
 162 susceptibility in a preferred direction, and it can be expressed by a magnetic  
 163 susceptibility ellipsoid with three mutually perpendicular susceptibility axes, i.e.  
 164  $K_1 \geq K_2 \geq K_3$  (Tarling and Hrouda, 1993; Borradaile and Jackson, 2004).  $K_1$  and  $K_3$   
 165 represent the magnetic lineation and pole to the magnetic foliation, respectively.  
 166 Moreover, several parameters were calculated with the measured values of  $K_1$ ,  $K_2$  and  
 167  $K_3$  by the program Anisoft (version 4.2, AGICO), for example, the mean bulk  
 168 magnetic susceptibility ( $K_m = 1/3(K_1 + K_2 + K_3)$ ), the corrected degree of anisotropy  
 169 ( $P_J = \exp\sqrt{2[(\eta_1 - \eta)^2 + (\eta_2 - \eta)^2 + (\eta_3 - \eta)^2]}$ ) and the shape parameter  
 170 ( $T = (2\eta_2 - \eta_1 - \eta_3) / (\eta_1 - \eta_3)$ ), where  $\eta_n = \ln K_n$  and  $\eta = (\eta_1 + \eta_2 + \eta_3) / 3$ .  $K_m$  indicates the mean  
 171 bulk magnetic susceptibility of different magnetic carriers, including the  
 172 ferromagnetic, paramagnetic and diamagnetic minerals, and the  $P_J$  and  $T$  values  
 173 represent the eccentricity and shape of the magnetic ellipsoid, respectively (Jelínek,  
 174 1978, 1981; Hrouda, 1982).

175 The mineralogical investigations, including thermomagnetic measurement,  
 176 Isothermal Remanence Magnetization (IRM) and hysteresis properties, were

177 conducted on representative samples to reveal the contribution of different magnetic  
178 carriers to the bulk magnetic susceptibility. The thermomagnetic measurements were  
179 performed at the Paleomagnetism Laboratory of Nanjing University with the CS3  
180 furnace coupled with a KLY-3S Kappabridge, and protective argon gas was used. The  
181 samples were heated from 50° to 700° with constant heating and cooling rate of  
182 9°/min. The hysteresis loops and IRM measurement were carried out at the Key  
183 Laboratory of Paleomagnetism and Tectonic Reconstruction of Ministry of Natural  
184 Resources (Beijing). Magnetic hysteresis loops and FORCs can reveal both the grain  
185 size and domain state of magnetic minerals and were obtained using a Lakeshore  
186 8600 Vibrating Sample Magnetometer (VSM). For the magnetic hysteresis loop  
187 experiments, the powdered samples were subjected to a cycled field of  $\pm 600$  mT. A  
188 slope correction was applied to remove the impact of paramagnetic contributions.

#### 189 ***4.2. Whole-rock major and trace element analyses***

190 Whole-rock major and trace element analyses were conducted at the ALS  
191 Chemex Co., Ltd (Guangzhou, China). The major element concentration was  
192 determined by an X-ray fluorescence (XRF) spectrometer with an analytical precision  
193 better than  $\pm 0.01\%$ . Trace elements were measured using PerkinElmer ICP-MS with  
194 an analytical precision better than  $\pm 5\%$  for most elements. Detailed analytical  
195 methods and procedures can be found in Liang et al. (2000).

#### 196 ***4.3 3D geometry modelling***

197 The 3D geometry of the Dongguashan quartz diorite stock and its related ore  
198 deposit was mainly defined by the borehole data from the Tongling Nonferrous

199 Metals Group Holdings Company. All these data were integrated in the Micromine  
200 and GOCAD platforms, and the boundary of the geological body at shallow levels  
201 (<-850 m) without borehole data was mainly deduced by using the Micromine  
202 platform with Kriging interpolation and smoothed at the COCAD platform. Detailed  
203 approaching process is reference to Liu et al. (2012).

## 204 **5. Results**

### 205 *5.1. Petrographic texture investigation*

206 A total of twenty-four core specimens were selected from forty-one AMS  
207 sampling sites to prepare the oriented thin sections for petrographic texture  
208 investigation (Fig. 6a). The Dongguashan quartz diorite mainly consists of plagioclase,  
209 K-feldspar, quartz, biotite, hornblende, and is associated with sphene, magnetite,  
210 pyrite, apatite and zircon (Fig. 6b-6e). Some of the Dongguashan quartz diorites  
211 display a porphyritic texture, characterized by relatively larger feldspar crystals (Fig.  
212 6b-6e). The minerals show a euhedral to sub-euhedral habitus, and no textures related  
213 to sub-solidus high temperature deformation have been observed. Sericitization is  
214 usually developed along the cleavage of the minerals (Fig. 6b). Magnetite and pyrite  
215 are widely distributed in all the samples and are present in interstitial clots and aligned  
216 parallel to the long axis of the minerals (Fig. 6f) or in interstitial crystals (Fig. 6g).

### 217 *5.2. AMS of the Dongguashan stock*

#### 218 *5.2.1 Rock magnetic minerals*

219 Six representative thermomagnetic measurements were performed. The heating  
220 curves show a gradual decreasing trend indicating the existence of paramagnetic

221 minerals (Fig. 7a-7f). A moderate to slight drop at 325 °C for the samples collected  
222 from the depths shallower than -670 m suggests the presence of pyrrhotite (Fig.  
223 7a-7d), and a rapid drop at 580 °C for all the samples is most likely due to the  
224 existence of magnetite (Fig. 7a-7f). An obvious increase of magnetic susceptibility  
225 during cooling implies that mineralogical phase transformation occurred during the  
226 thermal experiment, for instance, pyrrhotite and pyrite transformed into magnetite at ~  
227 500 °C (Dunlop and Özdemir, 1997). The shapes of the hysteresis loops of these  
228 samples are similar to that of ferromagnetic minerals (Fig. 7h-7j) with low values of  
229 magnetic coercivity (Fig. 7k-7m). Moreover, the isothermal remanence measurements  
230 show similar rapid increasing and saturation trend at ca. 300 mT (Fig. 7k-7m).  
231 Accordingly, the magnetic minerals in the Dongguashan quartz diorite are composed  
232 of paramagnetic minerals, e.g., biotite and feldspar, and low-coercivity ferromagnetic  
233 minerals, e.g., magnetite and pyrrhotite. The thin section observations show a  
234 relatively high volume-ratio of magnetite (Fig. 6e-6f), suggesting that the magnetite  
235 may be the major magnetic susceptibility carriers in the Dongguashan quartz diorite.

### 236 5.2.2. *Magnetic parameter data*

237 The magnetic parameters of quartz diorite in the Dongguashan stock, for  
238 instance,  $K_m$ ,  $P_J$  and  $T$ , are provided in Table 1, and  $K_m$  vs.  $P_J$  and  $T$  vs.  $P_J$  diagrams  
239 are presented in figure 8. More than 90% sites show high bulk magnetic susceptibility,  
240 i.e.  $K_m > 10^{-3}$  SI (Fig. 8a), confirming that these samples are dominated by the  
241 ferromagnetic minerals. Moreover, no linear correlation has been observed between  
242 the bulk magnetic susceptibility and corrected degree of anisotropy, denoting that the



243 magnetic fabric is mainly defined by the rock composition (Borradaile, 1988). Over  
244 seventy percent of sites have corrected degree of anisotropy values lower than 1.15  
245 (Table 1 and Fig. 8a), indicating that the magnetic fabric is mainly primary (Hrouda,  
246 1982; Rochette et al., 1992). The sites with high  $P_J$  value are close to the stock  
247 boundary, which may be due to the intense interaction of the magma intrusion with  
248 the country rocks (Table 1 and Fig. 8). The majority of shape parameter values are  
249 positive (Table 1 and Fig. 8b), suggesting the prevalence of oblate ellipsoids, except  
250 for samples collected from the south part of the stock, which are dominated by  
251 negative values (Table 1 and Fig. 9), and thus, prolate magnetic ellipsoids are  
252 suggested.

### 253 *5.2.3 Magnetic fabrics*

254 Detailed site-mean magnetic fabrics and their positions with respect to the  
255 restored stock boundary at depth are presented in Fig. 9. Most of these sites show well  
256 developed magnetic foliations with inclinations from highly inclined dipping ( $40^\circ$ ) to  
257 vertical ( $89^\circ$ ), except for sites DTS14, HSP25 and DGS34 with gentle inclinations of  
258 ca.  $20^\circ$  (Table 1 and Fig. 9). According to the strike of magnetic foliation, the majority  
259 of sampling sites are characterized by NE-SW-striking and SE dipping magnetic  
260 foliation, which are labeled as Group I (G-I; white stereographs in Fig. 9). Eleven  
261 sites located in the central-southern part of the stock with depths greater than -670 m,  
262 i.e. HSP16, HSP17, DTS18, DTS19, DGS20, HSP24, HSP25, DTS26, DTS27,  
263 HSP32 and HSP37 are classified in Group II (G-II; grey stereographs in Fig. 9). The  
264 sites in G-II display relatively consistent NW-SE-striking magnetic foliations and

265 steeper dipping angle than those in G-I (inserted stereographs in Fig. 10a and b). The  
266 magnetic lineations of G-I are characterized by highly variable plunges with  
267 directions sub-parallel or cross with the stock boundary (inserted stereograms in Fig.  
268 10b). Especially, the sites of G-I lower than -670m show gentle to sub-horizontal  
269 plunges of lineation (Fig. 10b). Nevertheless, the directions of magnetic lineation of  
270 G-II show a consistent NW-SE trending and variable plunges (Fig. 10c and d).

### 271 **5.3. Whole-rock major and trace elements geochemistry**

272 Six fresh and representative samples for geochemical analysis were collected at  
273 the -670m platform and sampling locations are the same as the AMS sampling (Fig.  
274 11a). The acquired geochemical data and previous geochemical analysis are presented  
275 in Table S1. Previous geochemical results of the Dongguashan stock are also included  
276 in Table S1 for a comprehensive and comparative analysis (Wang et al., 2003, 2015,  
277 Huang et al., 2004; Guo et al., 2013; Liu et al., 2018).

278 According to the  $\text{SiO}_2$  content, the analyzed Dongguashan quartz diorites and  
279 previous geochemical analysis present a wide range of  $\text{SiO}_2$  (56.5% to 65.32 wt.%)  
280 and the relatively low  $\text{SiO}_2$  content Group II (G-II: 56.48 – 60 wt.%; Table S1 and Fig.  
281 11). Moreover, G-I has a wider range of  $\text{SiO}_2$  content than that of G-II (Fig. 11b-h).  
282 The  $\text{TiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{CaO}$ ,  $\text{MgO}$ ,  $\text{Na}_2\text{O}$  and  $\text{P}_2\text{O}_5$  display steadily decrease or constant  
283 trend with increasing  $\text{SiO}_2$ , suggesting that the minor compatible behavior (Fig.  
284 11b-11g).  $\text{K}_2\text{O}$  shows constant or slightly increase in G-I with increasing  $\text{SiO}_2$  (Fig.  
285 11h), which may be due to the hydrothermal alteration during the subsequent  
286 mineralization process.

#### 287 **5.4. The 3D geometry of the stock and its related orebody**

288 The horizontal drilling sections and 3D geometry model of the Dongguashan  
289 quartz diorite stock and related orebodies (Fig. 12) highlight several major features of  
290 the Dongguashan quartz diorite stock. The stock has a complicated shape with a  
291 principal NE-SW extending long axis. Many apophyses are formed within the strata  
292 bedding (Fig. 12b, c and d) and the skarn orebodies are mainly developed in the  
293 northern hinge and eastern limb of the Qingshanjiao anticline. The largest ore, i.e. the  
294 Dongguashan ore, was yield between the Middle to Upper Carboniferous carbonates  
295 and Upper Devonian sandstone with depth ranging from ca. -650 m to -850m (Fig.  
296 12a), and the other two ore deposits, i.e. the Huashupo and Datuanshan ore deposits,  
297 are localized along the contact zones of the Dongguashan stock (Fig. 12).

### 298 **6. Discussion**

#### 299 **6.1. Significance of the petrofabric investigation**

300 The nature of the fabrics, i.e. whether primary or not, is pivotal for the  
301 interpretation. Our microscopic petrographic investigations on the Dongguashan  
302 quartz diorite and its country rocks show that the quartz diorite samples exhibit a  
303 typical magmatic texture, and intrusion-related ductile deformation was absent in the  
304 contact zone (Fig. 6). The dominantly low  $P_j$  values of the quartz diorite samples also  
305 suggest that the stock has not been significantly affected by a subsequent regional  
306 tectonic event (Hrouda and Lanza, 1989; Rochette et al., 1992). The ductile  
307 deformation of the country rock of the Dongguashan quartz diorite stock is apparent  
308 in folding and thrusting (Fig. 4f) that are considered to be inherited structures

309 resulting from the Triassic intracontinental event instead of resulted from magma  
310 emplacement (Deng et al., 2011; Mao et al., 2011; Wang et al., 2011).

311 Moreover, our magnetic mineralogical analyses suggest that major magnetic  
312 carriers of the Dongguashan quartz diorite are ferromagnetic and paramagnetic  
313 minerals. According to the microscopic observations, the arrangement of the  
314 magnetite and pyrrhotite is usually parallel to the long axis of the plagioclase and/or  
315 biotite (Fig. 6e and 6f), indicating that the magnetic fabric ellipsoid is parallel to the  
316 principal finite strain axes inferred from the petrographic fabric. Namely, the K1 and  
317 K3 magnetic axes correspond to the mineral lineation and the foliation pole,  
318 respectively. Consequently, we argue that the magnetic fabrics of the Dongguashan  
319 quartz diorite revealed by our AMS investigation were primary fabric, which can be  
320 used to reveal the magma emplacement process.

## 321 ***6.2. Interpretation of AMS results of the Dongguashan stock***

322 As mentioned above, the most remarkable feature of the AMS results of the  
323 Dongguashan quartz diorite is the coexistence of two nearly orthogonal magnetic  
324 fabric groups, i.e. G-I and G-II. Thus understanding of the magnetic fabric of the  
325 Dongguashan quartz diorite stock is essential for the re-construction of the magma  
326 emplacement process. The 3D geometry modelling of the Dongguashan quartz diorite  
327 stock (Fig. 12) and a previous geobarometric study indicate that the stock has a small  
328 volume and shallow emplacement depth (ca. 4-6 km; Du et al., 2004). Therefore, we  
329 consider that the Dongguashan stock should be a rapidly emplaced and cooled stock,  
330 in terms of previous studies on the duration of pluton construction (Matzel et al., 2006;

331 de Saint Blanquat et al., 2011). Consequently, this distinct magnetic fabric pattern  
332 cannot be produced by magma convection in the magma chamber at emplacement  
333 crust level, and detailed discussion of the AMS result is described below.

#### 334 *6.2.1. AMS results for Group I*

335         Seventy-eight percent of the magnetic foliation of G-I is characterized by a  
336 NE-SW strike with steep or high-angle southeastward dip (Fig. 10 and Table 1). This  
337 pattern of relatively consistent strike and dip of the magnetic foliation in the  
338 Dongguashan quartz diorite stock is different from previous AMS studies on other  
339 stocks around the world, which usually present a circular array of inward dipping  
340 magnetic foliations with strike parallel to the stock boundary (Cogné and Perroud,  
341 1988; Hrouda and Lanza, 1989; Romeo et al., 2008; He et al., 2009; Piña et al., 2010).  
342 Whereas the trend and plunge of magnetic lineation of these sites are highly variable  
343 (Fig. 10c and 10d), which is a typical feature for the fabric developed in a stock  
344 (Cogné and Perroud, 1988; Hrouda and Lanza, 1989; de Saint-Blanquat, et al., 2001).  
345 This specific magnetic fabric pattern might be produced by the NW-SE directed  
346 regional shortening setting or be affected by the pre-emplacement NE-SW-striking  
347 structures in the country rocks. Nevertheless, previous studies suggest that the  
348 Tongling Ore Cluster is mainly under extensional regime during the magma  
349 emplacement epoch (e.g., Mao et al., 2003; Li et al., 2014). The petrographic  
350 investigations on the stock and its country rocks also suggest that the Dongguashan  
351 stock was not significantly influenced by any syn-magmatism and post-solidus  
352 regional tectonics. Hence, these evidence seem to be inconsistent with the first

353 possibility. Alternatively, considering the parallelism between the pre-emplacment  
354 fold and fault system developed in the country rocks and the NE-SW-striking  
355 magnetic foliation, we propose that these pre-emplacment structures may serve as  
356 magma ascent paths to form the NE-SW trending steep magnetic foliations, thus the  
357 magma ascent was principally driven by its buoyancy (Marsh, 1982; Clark et al., 1998;  
358 Paterson and Jr, 1993).

359 In particular, there are seven sites located at depths of -730m, -790m, and -850m  
360 of G-I show the strike of magnetic foliation crosscutting the stock boundary with  
361 mainly sub-vertical to northward dip (Fig. 10a). The magnetic lineation is mainly  
362 trending NE-SW or E-W with sub-horizontal plunges. This phenomenon may be due  
363 to the boundary effect, complex magma flow or magma outflow (e.g., Ferré et al.,  
364 2002; Kratinová et al., 2006). The borehole data also confirms that the Dongguashan  
365 quartz diorite intrusion was intruded into the stratigraphic interface at these depths  
366 (Fig. 12; Liu et al., 2014).

#### 367 6.2.2. AMS results for Group II

368 The magnetic fabric of G-II is characterized by consistent NW-SE-striking  
369 magnetic foliation and lineation, and this preferred orientation is roughly  
370 perpendicular to those of G-I and the NE-SW-striking regional structures. In addition,  
371 we have observed pervasively developed NW-SE striking fractures, calcite veins and  
372 vein-type orebodies in the Dongguashan stock and its country rocks (Fig. 5), which  
373 are parallel to the strike of the magnetic fabric of G-II. The NW-SE oriented magnetic  
374 fabrics, fractures and veins may be produced either by regional shortening in NW-SE

375 direction, or the magma was intruded into the NW-SE striking brittle structures, which  
376 produced by the overall extension of the upper crust in the Early Cretaceous epoch.  
377 However, contemporaneous Early Cretaceous magmatism is widely developed in the  
378 TOC, which is usually display a high-k and calc-alkaline affinity and considered to be  
379 a consequence of the regional extension (Wang et al., 2003; Wu et al., 2010; Guo et al.,  
380 2013; Zhou et al., 2015). Therefore, the hypothesis of the regional shortening is not  
381 preferred, we thus propose that the G-II magma emplacement was affected by overall  
382 extension of the upper crust.

### 383 ***6.3. Overview of research and tentative magma emplacement model proposal***

384 Apart from the difference in the AMS results, a sharp intrusive contact was  
385 observed at -670 m platform (Fig. 13), suggesting that the Dongguashan was  
386 constructed by multiple magma pulses. In addition, this and previous geochemical  
387 studies on the Dongguashan quartz diorite stock show that the major elements have a  
388 wide composition range (Fig. 11 and Table S1), which may result from fractional  
389 crystallization or multiple magma pulses emplacement model. Although the major  
390 elements seem to be distributed along a regression line, whereas the higher SiO<sub>2</sub>  
391 content samples were collected from the outer and deeper parts of the stock compared  
392 with the less silica-rich samples (Fig. 11). This distribution opposes the normal  
393 fractional crystallization trend in a gradual cooling magma chamber (Tindle and  
394 Pearce, 1981; McNulty et al., 2000; Coleman et al., 2004). Gradual petrological  
395 change or composition zoning related to fractional crystallization is also absent in the  
396 stock. Therefore, the fractional crystallization process seems not suitable to explain

397 the composition variation of the Dongguashan stock. Furthermore, previous  
398 geochronological studies in the Shizishan orefield also present a wide age spectrum,  
399 indicating a relatively long time magma emplacement process (Wu et al., 2010; Yang  
400 and Lee, 2011; Guo et al., 2013; Wang et al., 2015; Liu et al., 2018). In summary, all  
401 these evidence suggest that the Dongguashan quartz diorite stock was constructed by  
402 multiple magma pulses, and a two-stage magma emplacement model is proposed for  
403 the Dongguashan quartz diorite stock as described below.

404 On account of the samples of G-I are located in the outer part of the stock from  
405 -850m to -390m, and the samples of G-II are collected in the inner part of the stock  
406 with depths lower than -650 m. Moreover, the strike of magnetic foliation of G-I is cut  
407 by the G-II (Fig. 10). Therefore, we suggest that G-I and G-II belongs to the earlier  
408 and late magma pulses emplacement stages, respectively.

409 First, the initial magma emplacement occurred when the internal buoyancy  
410 force of the deeply seated magma chamber exceeded the lithostatic pressure of the  
411 country rocks (Fig. 14a; van der Molen and Paterson, 1979; Bachmann and Bergantz,  
412 2004; Vigneresse, 2007). Previous studies suggest the existence of NE-SW-striking  
413 basement faults in the crust, and the upper crust was deformed by Triassic  
414 pre-emplacement regional tectonics (Deng et al., 2006), which yielded paths or  
415 channels for the magma ascent (Fig. 14a). The decollement of country rocks produced  
416 part of the space for magma emplacement (Fig. 4f). Moreover, the abundance of  
417 xenoliths observed in the stock boundary suggests that the space for magma  
418 emplacement was partly created by magma stoping (Marsh, 1982; Clark et al., 1998).



419 The relatively more regular stock boundary in the western side of the stock than in the  
420 eastern one suggests an eastward magma accretion trend. The dilation (possibly  
421 controlled by hydrothermal fluids), inflation and uplifting of the brittle country rocks  
422 accommodated the gradual emplacement of magma (Fig. 14b).

423 Second, the consistent NW-SE-striking magnetic foliation of Group II samples  
424 and its parallelism with the NW-SE-striking fractures developed in the stock and  
425 country rocks, which produced by the regional extension, suggest that the  
426 emplacement of the late magma pulse was strongly controlled by these fractures (Fig.  
427 14c).

#### 428 ***6.4. Implications for the associated orebody localization***

429 Our study reveals that the Dongguashan stock was constructed by at least two  
430 magma pulses. Discontinuous magma emplacement changes the temperature field,  
431 fluid composition, oxygen fugacity and elements partition coefficients, and therefore  
432 is an important mechanism for the formation of huge intrusion related ore deposits  
433 (e.g., Holzheid and Lodders, 2001; Vigneresse, 2007; Huber et al., 2012;  
434 Chelle-Michou et al., 2015).

435 According to the restored 3D stock and orebody geometry model, the largest ore  
436 reserves are located at the Devonian-Carboniferous (D-C) stratigraphic interface with  
437 depth between ca. -650 and -950 m (Fig. 12). The occurrence of these stratiform  
438 orebodies is consistent with the flanks of the Qingshanjiao anticline, denoting that the  
439 hydrothermal fluid was intruded along the strata interface (Tang et al., 1998). The  
440 AMS results of the sites close to the stock boundary at depths of -670 to -850 m

441 suggest that magma outflow occurred within these strata, which is also supported by  
442 tiny and rootless granitic body revealed by borehole data (Fig. 12). Previous  
443 geochemical studies also suggest that the magma is the dominant source of  
444 ore-forming fluid. Thus, the stratiform skarn orebodies were mainly yielded by the  
445 early emplaced magma pulse, which was emplaced along pre-emplacment structures  
446 or discontinuous mechanical interfaces in the country rocks.

447 The second orebody localization zone concerns the contact zone between the  
448 stock and country rock. This includes the Huashupo and Datuanshan skarn-type  
449 orebodies, which are developed at the eastern side of the stock at depths of -300 to  
450 -600 m, and thus are related to the earlier emplaced magma pulse (Fig. 12). According  
451 to our study, the Dongguashan stock was constructed by successive magma pulses  
452 with an eastward accretion trend and forceful-like emplacement behavior. Thus, the  
453 country rock in the eastern side of the stock has a higher degree of deformation,  
454 intense fracturing and higher permeability and temperature, which were produced by  
455 the repeated magma intrusion. In addition, the restored 3D geometrical model shows  
456 that the occurrence of the orebody in the eastern side of the stock is roughly parallel to  
457 the stock-country rock contact surface, which dips gently outward in contrast to a  
458 sub-vertical contact in the western side (Fig. 12). Consequently, we propose that  
459 different interaction between the magma and country rock may affect the localization  
460 of the orebodies.

461 The third type of orebody, i.e. the vein-like and veinlet-disseminated orebodies,  
462 is widely developed inside the Dongguashan stock and partly developed in the

463 NW-SE-striking fractures (Fig. 5c and 5d). The parallelism among the ore veins, the  
464 strike of magnetic foliation of G-II and the fractures (Figs. 5 and 12) suggests that the  
465 space for the vein-like orebody was controlled by the later magma pulse.

## 466 **7. Conclusions**

467 According to our macro- and microscopic observations, geochemical and AMS  
468 analyses and 3D geometrical modelling of the Dongguashan stock, we concluded that:

469 1) The Dongguashan stock was constructed by at least two stages magma  
470 emplacement. The AMS results of these two magma stages can also be divided into  
471 two groups, i.e. G-I and G-II, corresponding to earlier and later magma pulses,  
472 respectively. G-I is dominated by a NE-SW striking magnetic foliation, which is  
473 parallel to the trend of the pre-emplacment folds and faults, suggesting that the  
474 magma emplacement was probably affected by the pre-emplacement structure. G-II is  
475 characterized by a NW-SE-striking magnetic foliation, which is parallel to the  
476 regional extensional structures, suggesting the control of regional extension on  
477 magma emplacement.

478 2) The 3D geometrical modelling of the stock presents a triangular shape with  
479 irregular and bulged boundary in the eastern side of the stock, denoting that the stock  
480 was constructed by an eastward magma accretion.

481 3) The AMS results suggest that the magma was intruded into the strata  
482 interface at depths between -670 to -850 m, which is the essential factor for the  
483 formation of the stratiform ore deposit in the Dongguashan area. Moreover, the  
484 eastward magma accretion resulting in highly fractured and more permeable country

485 rocks in the eastern stock contact zone that can explain why the skarn orebodies are  
486 localized in the eastern stock contact zone. The NW-SE-striking ore veins were likely  
487 controlled by the emplacement of the late magma pulse under an extensional regional  
488 tectonic setting.

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## 876 **Figure and Table captions**

877 **Fig. 1** (a) Tectonic sketch map of mainland China; (b) Distribution of the major  
878 Cretaceous igneous rocks and related mineral deposits in the Middle-Lower  
879 Yangtze Metallogenic Belt (modified from Pan and Dong, 1999; Mao et al.,  
880 2011).

881 **Fig. 2** Simplified magmatism-structural map of the Tongling district, Anhui province,  
882 China (The map is modified from the 1:50, 000 geological maps made by the 321  
883 geological team in Anhui province, 1989).

884 **Fig. 3** Geological map of the Shizishan Orefield. The Dongguashan stock is delimited  
885 by the dashed line. The age data presented in the map are collected from Wu et al.,  
886 2008; Xie et al., 2009; Xu et al., 2008; Guo et al., 2013; Liu et al., 2018.

887 **Fig. 4** (a), (b) and (c) Field observations of the Dongguashan quartz diorite stock; (d)  
888 and (e) Irregular intrusive contact and country rock xenoliths developed in the  
889 Dongguashan stock; (f), (g) and (h) Highly deformed country rocks and its  
890 deformation characters.

891 **Fig. 5** (a) Restored 3D geometry of the Dongguashan stock with locations of major  
892 orebodies. (b) Stratiform orebody developed in the contact. (c) Massive  
893 chalcopryrite orebody in the stock boundary. (d) vein-type orebody inside the  
894 Dongguashan stock. (e) Southwest dipping syn-tectonic calcite vein in the  
895 country rocks. (f) and (g) show the lower hemisphere projection  
896 (Schmidt-Lambert projection) of conjugated ore veins and extensional fractures,  
897 respectively.

898 **Fig. 6** (a) Cross profiles of cylinder core specimens prepared for oriented thin section.  
899 (b) to (g) Photomicrographs of thin sections of the representative quartz diorite in  
900 the Dongguashan stock. Abbreviations: Bt-Biotite, Hbl: Hornblende, Kfs:  
901 Potassium feldspar; Mt: Magnetite; Pl-Plagioclase, Qtz: Quartz; Ser: Sericite; Sph:  
902 Sphene.

903 **Fig. 7** Harker diagrams for variation of SiO<sub>2</sub> with other major elements from this and  
904 previous studies (solid grey symbols). Samples with high and low content of SiO<sub>2</sub>  
905 are classified into Group I and Group II, respectively. Detailed data are listed in  
906 supplementary Table S1.

907 **Fig. 8** Results of magnetic mineralogy analysis of representative quartz diorite  
908 samples from the Dongguashan stock. (a-f) thermal magnetic curves; (h-i)  
909 hysteresis loops, corrected for the paramagnetic linear trend; (k-m) isothermal  
910 remnant magnetization acquisition curves and backfield applications.

911 **Fig. 9** Correlation of the magnetic parameters. a)  $K_m$  vs.  $P_J$  and b)  $T$  vs.  $P_J$ .

912 **Fig. 10** Detailed AMS results of the Dongguashan quartz diorite. The white and grey  
913 stereograms are for Group I and Group II, respectively.

914 **Fig. 11** (a) Magnetic foliation of the Dongguashan stock and stereogram of foliation  
915 poles, (b) Stereograms of poles of magnetic foliation for samples in Group I and  
916 Group II, respectively. (c) Magnetic lineation of the Dongguashan stock with  
917 inserted stereogram. (d) Stereograms of magnetic lineation for samples in Group I  
918 and Group II. All the projections are equal area and lower-hemisphere.

919 **Fig. 12** (a) 3D geometric model of the Dongguashan quartz diorite stock and its  
920 related ore deposits, (b), (c) and (d) Representative drilling profiles of the  
921 Dongguashan, Datuanshan and Huashupo ore, respectively.

922 **Fig. 13** (a) Photograph and (b) sketch of intrusive contact in the Dongguashan stock.

923 **Fig. 14** Cartoon of the magma emplacement mechanism of the Dongguashan stock.

924

925 **Table 1** Sampling information and site-mean values of AMS results of the

926 Dongguashan quartz-diorite stock.

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929 **Highlights**

930 ● The Dongguashan quartz-diorite stock was built by multiple magma pulses

931 ● Early magma pulse was guided by inherited NE-SW-trending structure in country

932 rock

933 ● Late magma pulse emplacement was assisted by regional extensional regime

934 ● Eastward magma emplace might control location of skarnization in stock eastern

935 side

936

937

**Table 1. Sampling information and site-mean AMS results of the Dongguashan stock.**

Site	Litho.	Depth (m)	n	Km( $10^{-6}$ SI)	$P_f$	T	Site mean AMS		
							$K_I$	$\alpha_{95}(\text{max/min})$	D
							Dec (°)/Inc(°)	(°)	
HSP01	Qtz-diorite	-390	7	5010	1.14	0.04	250.2/70.4	15.4/4.9	
HSP02	Qtz-diorite	-390	5	17700	1.20	-0.08	111/46.3	16.5/13.2	
HSP03	Qtz-diorite	-390	5	6080	1.24	0.66	189.4/16.9	22.1/5.1	
DTS04	Qtz-diorite	-390	5	5400	1.18	0.08	141.4/82.7	17.1/10.4	
DTS05	Qtz-diorite	-390	5	662	1.02	0.03	222/56.1	22.8/11.6	
HSP06	Qtz-diorite	-460	6	1430	1.10	0.50	209.1/60.7	25/20.2	
DTS07	Qtz-diorite	-460	5	6380	1.10	-0.31	107.7/46.4	7.8/5.3	
DTS08	Qtz-diorite	-460	7	17800	1.13	0.63	267.9/36.3	19.2/6.2	
DTS09	Qtz-diorite	-460	7	11000	1.14	-0.44	186.8/81.1	16.7/8.2	
DTS10	Qtz-diorite	-460	6	977	1.03	0.02	48.5/12.4	5.4/3.9	
HSP11	Qtz-diorite	-580	5	2510	1.24	0.20	169.5/33.2	21.5/11.9	
HSP12	Qtz-diorite	-580	5	16200	1.06	0.39	227.9/23.4	11.3/7	
DTS13	Qtz-diorite	-580	5	5090	1.13	-0.07	132.4/68.4	18.2/16.9	
DTS14	Qtz-diorite	-580	5	1860	1.07	-0.14	67.9/2.1	9.6/4	
DTS15	Qtz-diorite	-580	5	2050	1.12	0.22	201.1/62.1	11.5/5.1	



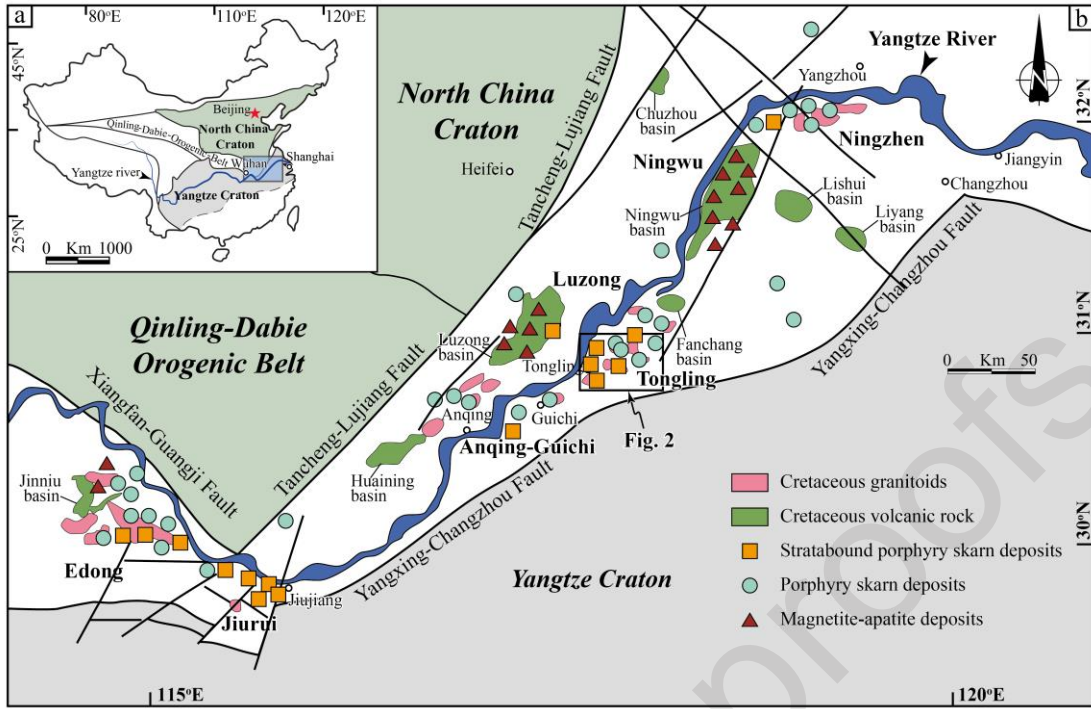
HSP16	Qtz-diorite	-670	5	8240	1.12	0.53	152.1/51.8	35.5/12.8
HSP17	Qtz-diorite	-670	5	12900	1.09	0.24	317.1/63.5	18.9/11.0
DTS18	Qtz-diorite	-670	6	4780	1.25	-0.46	137.7/72	8.1/4.1
DTS19	Qtz-diorite	-670	6	4120	1.18	0.59	135.8/17.5	51.7/13.2
DGS20	Qtz-diorite	-670	7	30200	1.08	-0.25	122.6/40.1	25.8/8.5
DGS21	Qtz-diorite	-670	6	9520	1.05	0.26	236.9/3.8	36/15.8
DGS22	Qtz-diorite	-670	5	859	1.10	0.30	260.7/37.9	38.3/13.6
DGS23	Qtz-diorite	-670	5	13900	1.10	0.08	280.5/74.3	44.6/5.1
HSP24	Qtz-diorite	-730	6	14100	1.18	-0.38	120.8/37	5.1/0.8
HSP25	Qtz-diorite	-730	5	25000	1.05	0.29	163.8/8.3	32.7/8.3
DTS26	Qtz-diorite	-730	6	16000	1.12	-0.32	319.5/19.5	7.2/3.6
DTS27	Qtz-diorite	-730	6	3380	1.12	-0.20	168.9/8.6	13.8/5.7
DGS28	Qtz-diorite	-730	6	52400	1.06	-0.02	216.4/15.3	21.7/4.1
DGS29	Qtz-diorite	-730	5	6000	1.15	0.40	263.5/27.2	63.5/5.9
DGS30	Qtz-diorite	-730	6	19900	1.06	0.11	236.1/35.8	15.3/10.7
DGS31	Qtz-diorite	-730	5	4670	1.06	0.04	300.2/10.8	5.4/4.2
HSP32	Qtz-diorite	-790	7	3650	1.22	0.21	152.6/38.2	21.3/6.4
DGS33	Qtz-diorite	-790	5	12100	1.10	0.14	224.6/65	7.8/4.5
DGS34	Qtz-diorite	-790	5	2380	1.05	-0.11	90.1/1.1	9.8/2.7
DGS35	Qtz-diorite	-790	5	39000	1.12	0.24	131/6.9	26.5/10
DGS36	Qtz-diorite	-790	7	164	1.03	0.12	275.3/2.5	15.4/5.3
HSP37	Qtz-diorite	-850	6	14400	1.19	0.14	144.9/74.1	12.1/8.9
DGS38	Qtz-diorite	-850	5	19900	1.10	-0.04	262.8/37.6	23.5/6.0
DGS39	Qtz-diorite	-850	5	41300	1.21	0.52	49.1/49.3	23.6/5.2
DGS40	Qtz-diorite	-850	5	171000	1.25	0.36	184.0/45.9	47.8/12.5
DGS41	Qtz-diorite	-850	5	33400	1.14	0.09	140.2/73.3	14.9/10.9

938 Note:

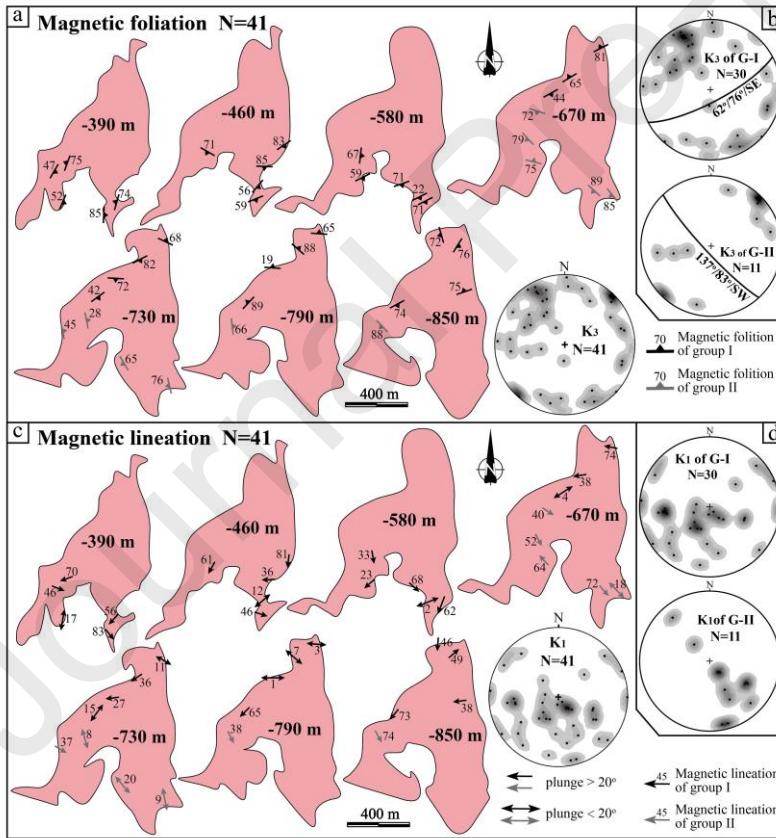
939 (1) Site: sampling site, n: number of specimen at sampling site; Km: bulk magnetic  
 940 susceptibility, P<sub>1</sub>: degree of susceptibility anisotropy, T: shape parameter of the AMS ellipsoid,  
 941 K<sub>1</sub>: Magnetic lineation, K<sub>3</sub>: The pole of the magnetic foliation, Inc.: Inclination, Dec.:  
 942 Declination,  $\alpha_{95}$  (max/min): the long and short axes of the confidence ellipsoid at 95% level.

943 (2) The unfilled and light grey filled lines represent the data of the Group-I and Group-II sites,  
 944 respectively.

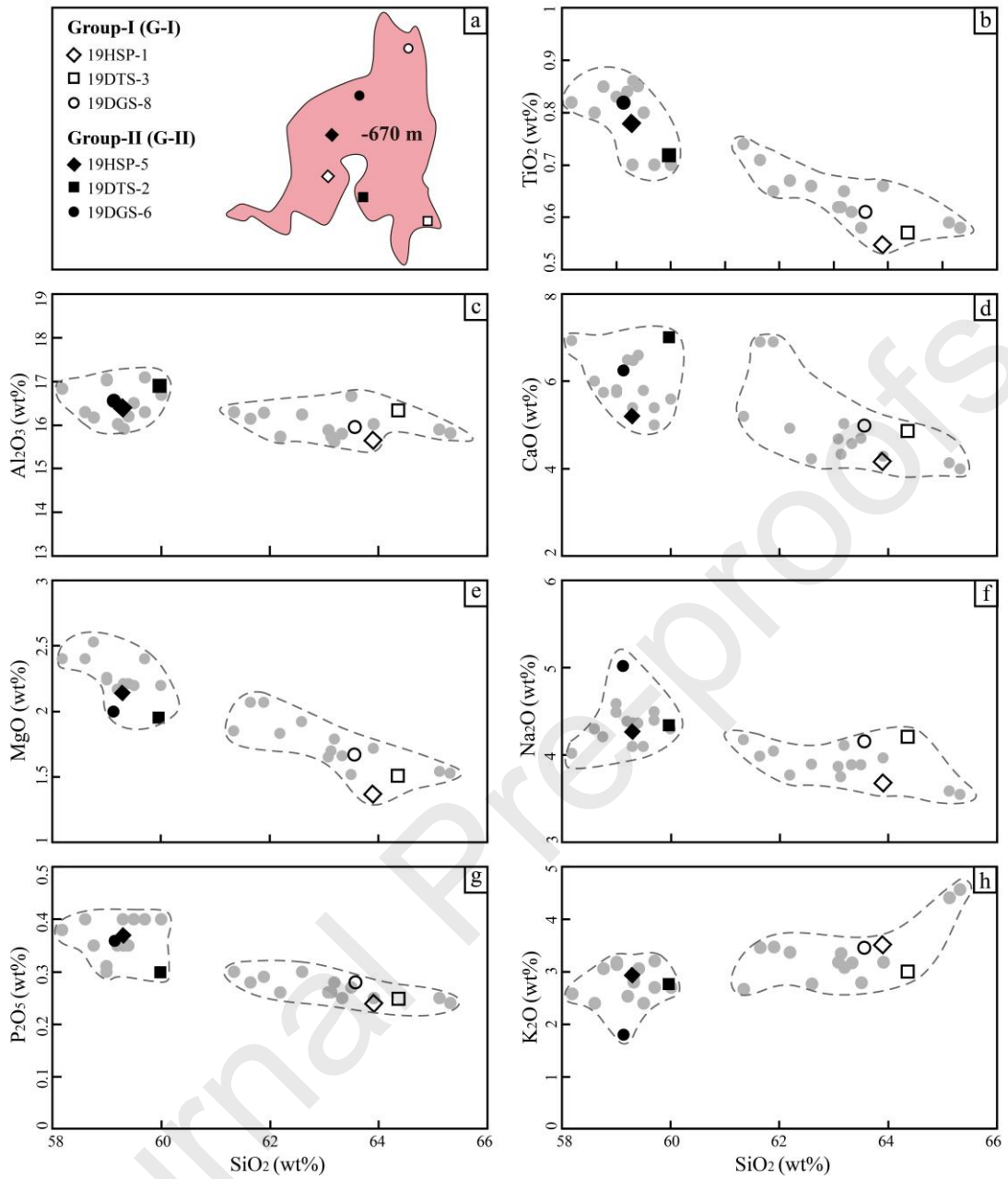
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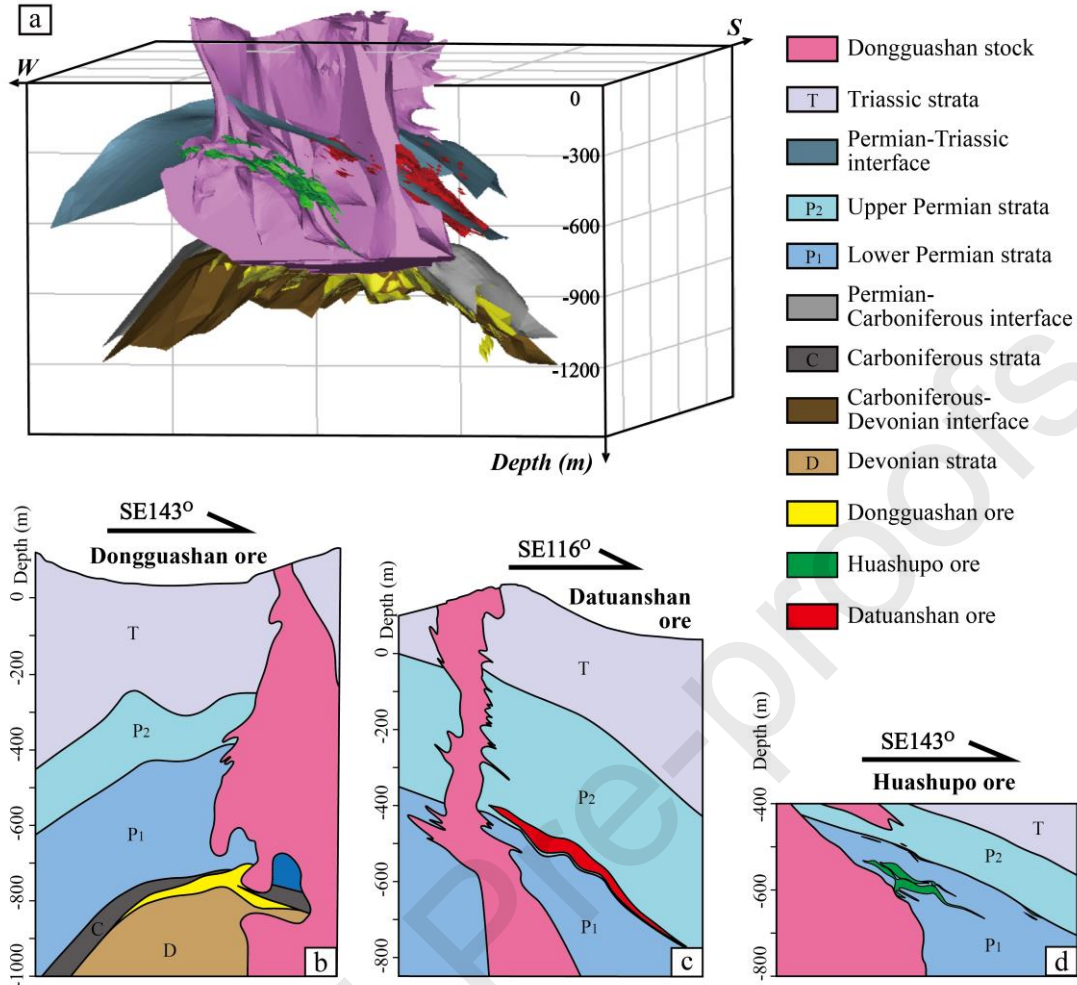


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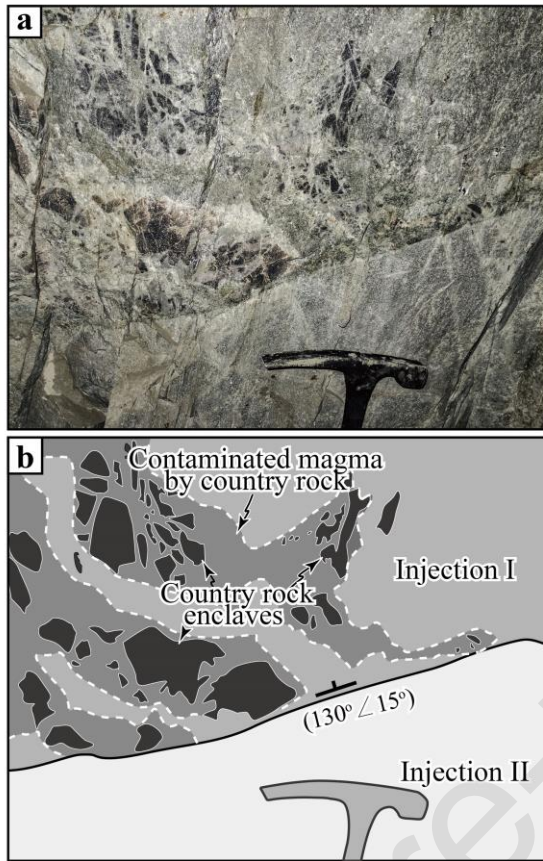


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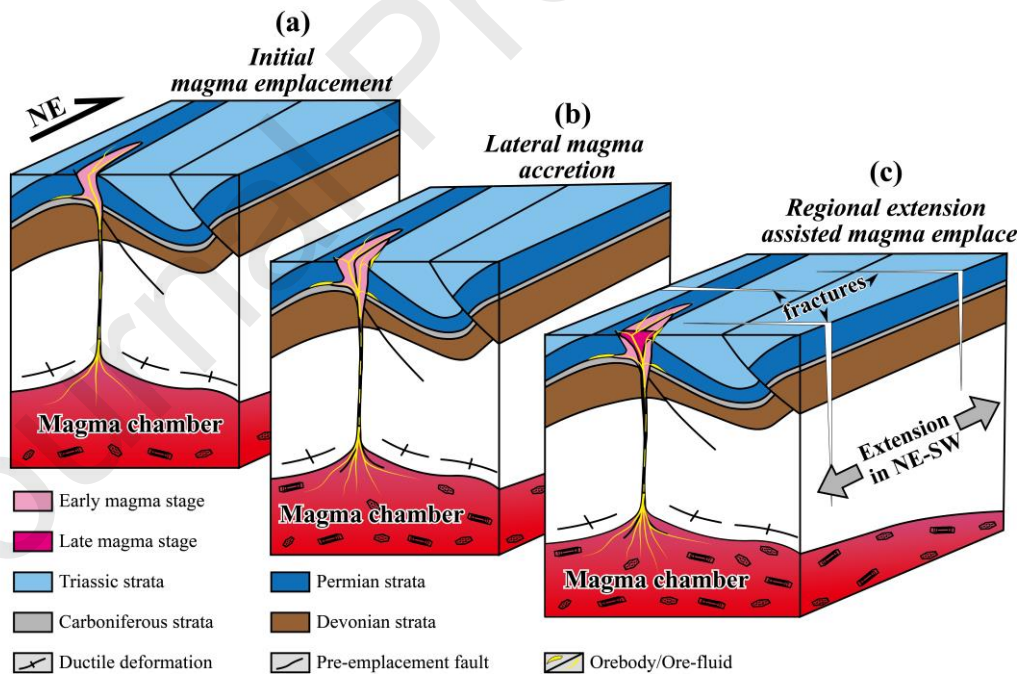








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