

## ***Interactive comment on “Effect of chemical composition on the electrical conductivity of gneiss at high temperatures and pressures” by Lidong Dai et al.***

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Interactive comment on “Effect of chemical composition on the electrical conductivity of gneiss at high temperatures and pressures” by Lidong Dai et al. Anonymous Referee 1: This article reports the effect of chemical composition on the electrical conductivity of biotite-bearing felsic gneiss at high P-T conditions. They tried to explain the conductivity differences by the contribution of total  $K^{++}Na^{++}Ca^{2+}$  of three natural gneiss samples. The experimental technique is top-notch but the strategy and discussion are not convincing. Thanks for the positive comments. In this revised manuscript, we conscientiously read through all valuable comments and suggestions, and revised each

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one points by points, sentences by sentences. So far we have made some substantial strategy and discussion convinced in the revised manuscript.

1. I think the manuscript must be revised largely and more evidences should be provided before publication. The authors measured the electrical conductivity of gneiss parallel to foliation. There are at least two reasons may contribute to the conductivity differences, including chemical composition effect and textural difference. How to evaluate the effect of textures? Biotite usually deforms and aggregates to form the band texture and it may exhibit strong conductivity anisotropy, highest along the layered surface and lowest perpendicular to the layered structure. The conductivity differences, therefore, may result from the texture differences. The authors did not describe the samples carefully. Thanks for your valuable and professional comments and suggestions. Indeed, just as described by the first anonymous reviewer, it is possibly existing two dominant reasons of chemical composition and texture that can result in the difference of electrical conductivity measurement results. Based on the results of the previously reported studies, the main conduction mechanism for phlogopite is ionic conduction, and  $K^+$  is proposed to be the main charge carriers (Li et al. 2017a, b). We suggested that the charge carriers of the gneiss samples were  $K^+$ ,  $Na^+$  and  $Ca^{2+}$ . Therefore, the influence of biotite on the conductivities of gneiss has been taken into consideration. On the other hand, the electrical conductivities of the gneiss samples don't regularly increase with increasing content of biotite, as shown in Table 1 and Fig. 6. Based on all of these obtained experimental results, it made clear that the content of biotite is not the main influence factor influence on the electrical conductivity of gneiss samples. In the present studies, we considered the gneiss sample as a whole to explore its electrical conductivity at high temperature and high pressure, and it is crucial that the chemical composition of sample ( $WA = Na_2O + K_2O + CaO = 7.12$  On the base of the valuable suggestion from the anonymous reviewer, we have already supplemented a large quantity of detailed description in the section of 2.1 sample preparation in the revised manuscript. Some main revisions have been summarized as follows: Three relatively homogeneous natural gneiss samples with a parallel to foliation direction

were collected from Xinjiang, China. The surface of the sample is fresh, non-fractured and non-oxidized, without evidence of alteration before and after experiments. The main rock-forming minerals of three gneiss samples are feldspar, quartz and biotite, respectively. It was indicated that three gneiss samples have the same mineralogical assemblage, and all of them belong to biotite-bearing felsic gneiss. From Table 2, we found that the totally alkali- (such as  $K^+$  and  $Na^+$ ) and alkali-Earth ( $Ca^{2+}$ ) metallic ion content for each sample were various. And therefore, in the present studies, we have conducted a series of experiments in order to determine the influence of chemical composition by changing the totally alkali- and alkali-Earth metallic ion content on the electrical conductivity of gneiss at high temperature and high pressure.

2. Even that the effect of chemical compositions dominates on the conductivities, the authors cannot use the composition data of a whole rock as that of the unique sample used in conductivity measurement because of the inhomogeneity. To overcome these uncertainties, well mixed powder samples must be used instead although the geological application will be penalized. Thanks for your professional comments and advisements. Indeed, it is one inevitable problem of the sample's inhomogeneity only if the researcher tried to measure the electrical conductivity of natural rock at high temperature and high pressure. Just as described by the anonymous reviewer, it's true that chemical composition for hot-pressed sintering sample by the mixed powder samples seems much more homogeneous than those of natural samples. In this study, we chose a series of natural samples rather than hot-pressed sintering sample, mainly considered: (a) the structure of mixed powder sample is completely different from that of natural sample, which implies that the natural sample become more representative to explore its geophysical implications; (b) In the process of hot-pressed sintering sample, grain size is difficult to control for each experiment, and therefore, the grain size influence on the electrical conductivity issue for one complex rock is not easy to be well solved; (c) Only if one natural rock sample of its mineralogical assembly contained one or several hydrous minerals, such as amphibole, mica et al., it is not strongly suggested that we chose one hot-pressed sintering method to synthesize the starting experimen-

tal sample. If the hot-pressed temperature is too low, I am afraid that some inevitable fractures and microcrackings have some influences on the subsequent electrical conductivity measurement. On the contrary, if the hot-pressed temperature is too high, the dehydration of hydrous mineral must be full considered in the process of sample preparation. As a matter of fact, in our previously reported papers, we have already completed electrical conductivity measurements on many representative natural rock samples at high temperature and high pressure in our laboratory, such as natural samples: pyroxenite (Dai et al. 2006), lherzolite (Dai et al. 2008), amphibolite (Zhou et al. 2011; Wang et al. 2012), granite (Dai et al. 2014), basalt (Dai et al. 2015), gabbro (Dai et al. 2015), and eclogite (Dai et al. 2016), etc. In addition, much more papers on the electrical conductivity of natural rocks have been also published in other laboratory, such as granulite (Fuji-ta et al. 2004), gneiss (Fuji-ta et al. 2007), amphibolite (Saltas et al. 2013), and quartzite (Shimojuku et al. 2014), etc. In addition, we made great efforts in choosing small area of three relatively homogeneous natural gneiss samples with a parallel to foliation direction in the process of our current sample preparation. During the conductivity measurements, we cut and polish them into a cylinder of  $\Phi$  6.0  $\times$  6.0 mm in order to efficiently avoid this issue. Of course, in the future, we can try to measure one hot-pressed synthetic gneiss sample and compare it.

3. It is also a strange strategy that the authors haven't choose the samples from Dabie-Sulu as the starting materials, despite finally they apply the results to explain the HCL within Dabie-Sulu. Thanks for your valuable comments. To be frank, due to some practical difficulties for our own work area, we didn't collect a series of natural gneiss samples originated from the region of Dabie-Sulu ultrahigh-pressure metamorphic belt. However, it has been confirmed that abundant felsic gneisses were widespread distributed in Dabie-Sulu ultrahigh-pressure metamorphic belt, and the mineralogical assemblage of gneiss in Dabie-Sulu ultrahigh-pressure metamorphic belt is similar to that of our present experimental samples (Gong et al. 2013). In addition, the gneiss distributed in the deep Earth interior may be existing some discrepancy from that of outcrop in the Earth's surface. Three gneisses with various chemical compositions are

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able to represent many natural biotite-bearing felsic gneiss, and we arrived in one conclusion that the electrical conductivities of gneiss cannot be used to interpret the high conductivity layers (HCLs) in Dabie-Sulu ultrahigh-pressure metamorphic belt.

Other comments: (1) Quality of writing: In its present state, this article is not publishable. Writing needs tremendous improvements to match the requirements of any peer-reviewed journal. As for the issue of English language, we appreciated Dr Aaron Stallard in Stallard Scientific Editing Company for their helps in English improvements of the manuscript. The substantial corrections for English have been conducted sentences by sentences. After that, the revised paper becomes much more easily be read and understood.

(2) The authors should calculate the activation volume for Run DS12, and explain the possible mechanism of positive pressure effect on the conductivity. According to the suggestion, we have already supplemented all of these results on the activation volume for Run DS12 and the calculating equation. With increasing pressure, the electrical conductivity of gneiss increases, accordingly. The activation volumes for Run DS12 are -7.10 cm<sup>3</sup>/mole and -2.69 cm<sup>3</sup>/mole at low temperature region and high temperature region, respectively. Another one representative metamorphic rock for gneiss, we can compared it with the electrical conductivity of eclogite. Recently, Dai et al. (2016) measured the electrical conductivity of dry eclogite, and the obtained negative activation volume value for eclogite is -2.51 cm<sup>3</sup>/mole under conditions of 1.0-3.0 GPa and 873-1173 K. It was proposed that the main conduction mechanism for dry eclogite is intrinsic conduction (Dai et al. 2016). The conduction mechanism for gneiss sample at high temperature region was also proposed to be intrinsic conduction, but the conduction mechanism at low temperature region was impurity conduction (possible charge carriers: K<sup>+</sup>, Na<sup>+</sup>, Ca<sup>2+</sup>, H<sup>+</sup>, et al.). In addition, it was suggested that the positive pressure effect on the electrical conductivities of gneiss samples may be due to the more complicated rock structure.

(3) Line 322-325: The authors should clearly show how to convert the conductivity

temperature data to conductivity-depth profile with the aid of heat flow for the general readers. Thanks for your professional and precious suggestions. The relationship between temperature and depth in the Earth's stationary crust can be described by a numerical solution of the heat conduction equation (Čermák and Laštovičková 1987): (1) where  $T_0$  is the surface temperature (K),  $Q$  is the surface heat flow ( $\text{mW/m}^2$ ),  $Z$  is the lithospheric layer depth (km),  $k$  is thermal conductivity ( $\text{W/mK}$ ), and  $A_0$  is the lithospheric radiogenic heat productivity ( $\mu\text{W/m}^3$ ). Based on previous studies, the thermal calculation parameters for Dabie-Sulu terrane are  $Q = 75 \text{ mW/m}^2$  (He et al. 2009),  $A_0 = 0.31 \mu\text{W/m}^3$ , and  $k = 2.6 \text{ W/mK}$  (Zhou et al. 2011). According to heat conduction equation and thermal calculation parameters, conductivity-temperature data can be converted to conductivity-depth profile for Dabie-Sulu terrane.

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