A Preliminary Report on the Experimental Study of the Two-pyroxene Andesite from Kuanyinshan, Northern Taiwan

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The high temperature furnace and the high pressure high temperature piston-cylinder apparatus were set up in the experimental petrological laboratory of Department of Earth Sciences, National Taiwan Normal University. The thermal gradient in the high temperature furnace is smaller than 1°C per 10 cm in the uniform zone. The precisions for the pressure and temperature measurements of the piston-cylinder apparatus are 0.3 kb and 5°C, respectively. The thermocouple used in the present experiments was calibrated and the temperature correction is -21.2°C. The liquidus temperatures of the Kuanyinshan andesite were determined to be 1210°C, 1250°C, and 1290°C at the atmospheric pressure, 10 kbar and 20 kbar, respectively. Near-liquidus minerals at atmospheric pressure are iron-titanium oxides and plagioclase. Plagioclase, however, is the near-liquidus mineral at 10 kbar and 20 kbar. The slope of the liquidus curve of the andesitic melt is about 40°C per 10 kbar.

Keywords: Andesite Liquidus Near-liquidus mineral

Introduction

Taiwan is in the collision area between the Eurasian plate and the Philippine plate. Based on the seismic studies, the Philippine plate bends along Ryukyu trench at about latitude 24° N latitude and dips northward with about 45° beneath the Eurasian plate (Tasi, et al., 1977; Kao and Wu, 1996). The magma activity created the Tatan and Kuanyinshan volcanoes may be related with the subduction after Pliocene. It is significant to study the petrogenesis of the Kuanyinshan volcanics for the special tectonic setting in this area.

Kuanyinshan volcano is situated in Taipei county, northern Taiwan. This volcano is mainly consisted of three successive andesitic lava flows. According to the mafic minerals of the rocks, two types of basalt and six types of andesite were found in this area (Ichimura, 1950; Chen, 1982). A caldera structure in the southeastern area was recognized by Chen and Hwang (1982) and Hwang and Lo (1986). The eruptive sequences of the lava flows were augite andesite lava, the first, two-pyroxene andesite lava, the second, and hyperssthene andesite lava, the third, as determined by Hwang and Lo (1986).

Based on the contact relationship between the volcanics and the surrounding sedimentary rocks, Yen (1958) inferred that the age of the Kuanyinshan eruption was between Plio-Pleistocene and middle Pleistocene. Juang and Chen (1989) dated the Kuanyinshan volcanics between 0.63 and 0.20 Ma with the potassium-argon method. The volcanic activity was traced back to 1.1 Ma by Wang (1989) with fission track method.

The geochemistry of the andesites and basalts
in the Kuanyinshan volcano shows that fractional crystallization may be the main mechanism for the petrogenesis in this area (Chen, 1982). The hornblende bearing two-pyroxene andesite from Kuanyinshan was studied by Liu and Huang (1983) up to 20 kb. Plagioclase and two-pyroxene are near liquidus minerals at lower pressure. At the pressure higher than 10 kb, two-pyroxene are the only near-liquidus minerals. It is interesting to estimate the pressure and temperature ranges of the fractionation for the whole series. In this paper, the preliminary experimental results of the Kuanyinshan andesite was presented and the high temperature high pressure laboratory at National Taiwan Normal University was introduced.

Experimental Method

Starting material

The two-pyroxene andesite used in the present experimental study was collected from Kanyinshan, northern Taiwan. It is grayish-white, porphyritic and vesiculated. The phenocrysts with about 50 modal percent in the sample are augite, plagioclase and hypersthene. The modes of augite and hypersthene are almost in equal amount. The zoning is clearly seen in some plagioclase. Some hypersthene occurs as corona around the augite. Phenocrysts are typically dispersed in an intergranular groundmass of plagioclase, augite, hypersthene, iron-titanium oxides, and glass. The whole rock chemistry was analyzed by X-ray fluorescence spectrometer at National Taiwan University and listed (in weight percent) as following: SiO₂: 56.93, TiO₂: 0.67, Al₂O₃: 18.42, total FeO: 6.03, MnO: 0.13, MgO: 5.43, CaO: 7.57, Na₂O: 3.01, and K₂O: 1.81. The rock powder was used directly as the starting material in this study.

Apparatus and procedures

1. At atmospheric pressure

The rock samples were crushed into pieces with the diameter smaller than one centimeter. The rock chips were ground into powder less than 200 mesh. The rock powder was loaded into platinum envelopes. The experiments were made by suspending the Pt envelopes with sample in a 1-atm vertical-quenching furnace following the Presnall's method (Figure 1) (Presnall, 1966). The thermal gradient in the uniform zone of the furnace is less than 1 °C per 10 cm (Figure 2).

Fig. 1 Schematic diagram on the arrangement of the high temperature experiment following Presnall's method in the quenching furnace at atmospheric pressure.
All temperatures were measured with a Pt-Pt₉₇Rh₁₃ thermocouple calibrated with the liquidus temperature of diopside (Table 1). The liquidus temperature of diopside is 1394.3 °C based on the International Practical Temperature Scale of 1968 (IPTS-68) (Anonymous, 1969). Therefore, the temperature read-out of the thermocouple should be corrected with +21.2 °C. Precision of the temperature measurements is estimated to be ±1 °C.

The run products were quenched by water in the end of the run by arcing the fine platinum wire with high voltage through the coarse platinum wire on the top (Figure 1). Durations of experiments for diopside and the andesite ranged from about 3 to about 23 hours and from 3 to 12 hours, respectively.

2. At high pressure

For the high pressure experiments, the runs were carried out in a piston-cylinder apparatus (Boyd and England, 1960). The model is Quick Press 3.0 type supplied by Depths of the Earth Company (Figure 3). Pressure is generated by pumping a hydraulic ram to force a piston into a pressure plate that consists of concentric layers of hardened-steel around a tungsten carbide core (Figure 4). The area ratio between the ram and the piston is 100:1. The operating pressure range is between 5 and 25 kbar with a precision of ±0.3 kbar for whole range.

![Schematic diagram](image)

**Table 1** The run data for diopside at atmospheric pressure

<table>
<thead>
<tr>
<th>Run no.</th>
<th>Temp (°C)</th>
<th>time (Hrs : Mins)</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>1418</td>
<td>23 : 07</td>
<td>Glass</td>
</tr>
<tr>
<td>11</td>
<td>1416</td>
<td>5 : 27</td>
<td>Glass</td>
</tr>
<tr>
<td>13</td>
<td>1415</td>
<td>4 : 27</td>
<td>Glass + Diopside</td>
</tr>
<tr>
<td>14</td>
<td>1414</td>
<td>22 : 15</td>
<td>Glass + Diopside</td>
</tr>
<tr>
<td>12</td>
<td>1413</td>
<td>17 : 19</td>
<td>Glass + Diopside</td>
</tr>
<tr>
<td>10</td>
<td>1412</td>
<td>3 : 25</td>
<td>Glass + Diopside</td>
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<tr>
<td>6</td>
<td>1406</td>
<td>20 : 16</td>
<td>Glass + Diopside</td>
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<td>7</td>
<td>1405</td>
<td>3 : 44</td>
<td>Glass + Diopside</td>
</tr>
<tr>
<td>8</td>
<td>1403</td>
<td>19 : 23</td>
<td>Glass + Diopside</td>
</tr>
<tr>
<td>9</td>
<td>1401</td>
<td>4 : 30</td>
<td>Glass + Diopside</td>
</tr>
<tr>
<td>1</td>
<td>1400</td>
<td>17 : 20</td>
<td>Glass + Diopside</td>
</tr>
<tr>
<td>2</td>
<td>1398</td>
<td>6 : 48</td>
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<tr>
<td>4</td>
<td>1393</td>
<td>15 : 20</td>
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</tr>
<tr>
<td>5</td>
<td>1391</td>
<td>3 : 30</td>
<td>Glass + Diopside</td>
</tr>
</tbody>
</table>

Fig. 2  The temperature distribution in the quenching furnace at the controlled temperature 1200 °C (longitudinal cross section view).

Fig. 3  Schematic diagram on the high pressure high temperature piston-cylinder apparatus (not to scale).
exact pressure for the run. The temperature for the high pressure experiments were measured with W5Re/W26Re thermocouple (Type C) with no pressure correction applied to emf values. Temperature were corrected to IPTS-68 (Anonymous, 1969). Each run was made as polished-section in the longitudinal orientation of the capsule and examined with the reflected light microscope.

Fig. 5 Furnace assembly for the high pressure high temperature experiment (not to scale).

Results and Discussions

The experiments for the diopside were designed near 1390 °C in the beginning. After several runs with the sub-liquidus results, the run temperatures were raised about 25 °C higher than the expected value (1394.3 °C for diopside on IPTS-68 scale). It was located finally between 1415 °C and 1416 °C runs (Table 1). The reason for the big correction (21.2 °C ) is that there is no ice point for the temperature read-out.

The liquidus curve of the two-pyroxene andesite between the pressure of 1 atm and 20 kbar, shown in Figure 6, is based on the quenching experiments listed in Table 2. The liquidus temperature at atmospheric pressure was determined at about 1210 °C. The liquidus temperatures of the Kuanyinshan andesite are 1250 °C and 1290 °C at 10 kbar and 20 kbar, respectively. The liquidus temperature of the andesite increases with the increasing pressure by about 40 °C per 10 kb in average within the experimental conditions.

Table 2 The run data for andesite

<table>
<thead>
<tr>
<th>Run no.</th>
<th>Pressure (kb)</th>
<th>Temp. (°C)</th>
<th>Time (Hrs:Mins)</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run A43</td>
<td>20</td>
<td>1300</td>
<td>12:00</td>
<td>Glass</td>
</tr>
<tr>
<td>Run A41</td>
<td>20</td>
<td>1280</td>
<td>5:00</td>
<td>Glass+Plagioclase</td>
</tr>
<tr>
<td>Run A37</td>
<td>15</td>
<td>1305</td>
<td>3:00</td>
<td>Glass</td>
</tr>
<tr>
<td>Run A35</td>
<td>10</td>
<td>1280</td>
<td>4:10</td>
<td>Glass</td>
</tr>
<tr>
<td>Run A34</td>
<td>10</td>
<td>1240</td>
<td>4:20</td>
<td>Glass+Plagioclase</td>
</tr>
<tr>
<td>Run A09</td>
<td>0.001</td>
<td>1212</td>
<td>4:40</td>
<td>Glass</td>
</tr>
<tr>
<td>Run A29</td>
<td>0.001</td>
<td>1208</td>
<td>10:00</td>
<td>Glass+Fe-Ti oxides +Plagioclase</td>
</tr>
</tbody>
</table>
The near-liquidus minerals at 1 atm are iron-titanium oxides and plagioclase. It could be inferred that the fractional crystallization of the andesite melt will be dominated by these two minerals at low pressure. The near-liquidus mineral at 10 kbar and 20 kbar is plagioclase. It implies that the andesitic melt may fractionate the plagioclase at the depth between 30 km and 60 km. It is valuable to make more runs to get more data points to cover the whole melting interval for the experimental pressure range. Furthermore, the residual melt, occurred as glass in the run products, should be analyzed with the electron microprobe. The compositions of the residual melts will provide us the information on the differentiation trend in this volcanic province.

The normal geotherms in the shield and ocean area are slightly off the scale in Figure 6 and are not shown. The andesitic magma may originate from basaltic magma through fractionations as suggested by Chen (1982). The basalt of Wannienta, which is a potential parental magma for the andesites in Kuanyinshan area, was simultaneously under investigation in this laboratory. The results of the studies will shed light on the petrogenesis of the Kuanyinshan volcano.

Conclusions

The thermocouple used in the present experiments was calibrated and the temperature correction is -21.2 °C. The liquidus temperatures of the Kuanyinshan andesite were determined to be 1210 °C, 1250 °C, and 1290 °C at the atmospheric pressure, 10 kbar and 20 kbar, respectively.

The near-liquidus minerals at atmospheric pressure are iron-titanium oxides and plagioclase. Plagioclase, however, is the only near-liquidus mineral at 10 kbar and 20 kbar. The slope of the liquidus curve of the Kuanyinshan andesitic melt is about 40 °C per 10 kbar.

References


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台灣北部觀音山地區兩輝安山岩
之初步實驗岩石學研究

劉德慶、陳博信、潘建熾、陳培凱、吳宜蓉
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本校地球科學系新成立實驗岩石實驗室擁有一台高溫爐（溫度可高達 1500 °C）和
活塞鋼筒高溫高壓儀一部（溫度可高達 2200 °C，壓力可達 25 千巴）。高溫爐爐內恆溫
區大於 10 公分，本實驗室之一號 R 型熱電偶，其校正值為 -21.2 °C。高溫高壓儀用途很
廣，可用來合成高溫環境下的礦物或材料，也可供研究材料在高溫高壓下的物理化學性
質；在岩石學方面，由於它可提供地底下深至 75 公里、溫度高達 2200 °C 的環境，很適
合做岩漿成因的模擬試驗。台灣北部觀音山下牛寮之兩輝安山岩初步研究顯示：其在
大氣壓、10 千巴和 20 千巴下之液相溫度分別為 1210 °C、1250 °C 和 1290 °C，液相溫度
在壓力每增加 10 千巴上升約 40 °C。近液相礦物在低壓範圍為鐵鈷氧化物和斜長石；及
至高壓區域，則為斜長石。

關鍵詞：安山岩  液相溫度  近液相溫度礦物