Introduction

The western Tianshan Mountain orogenic belt in Xinjiang Province, China, is an important part of the Central Asian Orogenic Belt and contains significant mineral resources (An and Zhu., 2008; Bai et al., 2011; Gao et al., 2009). The geology of this area is a microcosm of the typical magmatic and mineralizing processes that the Central Asian Orogenic Belt underwent in the Paleozoic, meaning that this area has been the focus of a significant body of research. More specifically, the majority of this research has focused on volcanic rocks of the Dahalajunshan Formation; these rocks preserve evidence of the effects of subduction on the tectonic history of the Central Asian Orogenic Belt.

Given the significant number of ore deposits in the western Tianshan area, it is important to identify the age of formation, the tectonic setting that volcanism occurred in, and the source characteristics of the magmas that formed the Dahalajunshan volcanics. Determining these factors will also further characterize the formation and evolution of the western Tianshan orogenic belt.

Geological setting and Petrography

The Yili–Central Tianshan Plate is located between the Junggar and Tarim plates. The Awulale area is located along the northern margin of the Yili–Tianshan Plate and consists, from north to the south, of the Late Paleozoic Lian Ha Bier trench–arc belt, the Early Paleozoic Boluokenu continental margin, the Dalati–Barron Block, and the Late Paleozoic Yi Erbin continental margin in the southern Tianshan Mountains, the latter outcropping in a wedge-shape that pinches out to the east. The Awulale area of the northern Yili–Central Tianshan Plate contains widespread and voluminous Early Carboniferous Dahalajunshan Formation (C1d) volcanics, including basalts, trachybasalts, basaltic andesites, andesites, and rhyolites (Li et al., 2011).

Volcanic rocks in the Awulale area consist of basalts and related rocks, and are dominated by trachybasalts, basaltic trachyandesites, and basaltic andesites, in addition to trachyandesites and rhyolites. The basalts are gray–green in color, have a granular texture, and are massive. Phenocrysts are dominated by plagioclase (15%–30% modal abundance) and clinopyroxene (5%–15%), with no olivine. Plagioclase phenocrysts range in size from 0.5 to 1.0 mm, are euhedral to subhedral, and are of oligoclase composition (An13–An26, Ab72–Ab86); the majority of clinopyroxene phenocrysts have been altered to chlorite and diopside. Andesites have porphyritic textures, and massive to block or fumarole structures. Phenocrysts within these andesites are mainly subhedral–euhedral plagioclase (45%–50% modal abundances) with minor amphibole (~5%) in a microcrystalline matrix of short prismatic plagioclase and volcanic glass. Rhyolites in the study area are porphyritic structure. They contain quartz, alkali feldspar, and plagioclase phenocrysts within a glassy matrix.

Geochemistry and Geochronology

Volcanic rocks in the study area are classified as basalts, trachybasalts, basaltic trachyandesites, basaltic andesites, trachytes and rhyolites on a total alkali vs. silica (TAS) classification diagram (Fig. 3). Basalts and trachybasalts have highly variable major element abundances, with basalts containing 47.47–52.00 wt% SiO2, and trachybasalts containing 0.85–2.00 wt% SiO2. Basalts and trachybasalts contain total alkali concentrations of 2.68–5.54 wt%, MgO concentrations of 3.29–9.13 wt%, and have Mg# values of 32.94–89.77,
where $\text{Mg}^# = 100 \times \frac{\text{Mg}^2+/\text{Mg}^{2+} + \text{Fe}^{2+}}{\text{Mg}^2+/\text{Mg}^{2+} + \text{Fe}^{2+}}$. Trachyandesites in the study area have high SiO$_2$ (57.77–58.21 wt%), total alkali (6.38–7.99 wt%), and MgO concentrations (2.59–4.19 wt%), and have high Mg$^#$ values (38.09–45.98), but low concentrations of TiO$_2$ (0.65–1.26 wt%) and P$_2$O$_5$ (0.17–0.46 wt%). Volcanic rocks in the study area have a wide range in total REE concentrations, with basalts and trachytic basalts containing SREE concentrations of 120.30–205.31 ppm, basaltic trachyandesites containing SREE concentrations of 69.98–147.78 ppm, trachyandesites containing SREE concentrations of 46.54–183.24 ppm, basaltic andesites containing SREE concentrations of 70.54–75.11 ppm, and rhyolites containing SREE concentrations of 94.78–102.23 ppm. These concentrations indicate that basaltic andesites and rhyolites contain relatively uniform low SREE concentrations.

Zircons from a rhyolite within the Beizhan mining area yielded a crystallization age of 316.1 ± 2.2 Ma, indicating that volcanism occurred in the Early Carboniferous, similar to a U–Pb zircon LA–ICP–MS age of 321.2 ± 2.3 Ma reported from volcanic rocks in the Chagangnuoer mining district, also within the Awulale area (Wang et al., 2011).

### 4 Discussion and Conclusions

1. The Dahalajunshan Formation volcanic rocks of the Awulale area are dominated by basalts, trachybasalts, basaltic trachyandesites, and basaltic andesites, with minor trachytes and rhyolites. LA–ICP–MS U–Pb dating of zircons from a rhyolite in this area yielded a crystallization age of 316.1 ± 2.2 Ma, indicating that these rocks formed in the late Early Carboniferous.  
2. The geochemistry of these volcanic rocks is indicative of a continental margin arc setting, with this arc forming during subduction of oceanic crust of the Junggar Ocean under the Yili Plate in the late Early Carboniferous. 
3. The magmas that formed these volcanic rocks were generated by 1%–5% partial melting of a region of mantle wedge that was previously metasomatized by fluids or melts derived from the subduction zone, with the magmas undergoing fractionation and crustal contamination during ascent and prior to eruption and emplacement.

### Acknowledgements

This study has been financially supported by National Physical Science Fund of China (no. 41372086), Key Laboratory of Gold Mineralization Processes and Resources Utilization Subordinated to the Ministry of Land and Resources(nos.2013014 and 2013015) and The Program for “Taishan” Scholars of Shandong Province.

### References


