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Early Carboniferous paleomagnetic results from the northeastern margin of the Qinghai–Tibetan plateau and their implications

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ABSTRACT

We conducted paleomagnetic investigations on limestone from the Lower Carboniferous Huaitoutala Formation in the Qaidam Basin near Delingha City, Qinghai Province, China. The characteristic remanent magnetization ($D = 5.8°$, $I = -25.7°$, $k = 114.3$, $\alpha_{95} = 4.8°$) passes a fold test and indicates a paleopole position of −39.2°N, 90.4°E and a paleolatitude of 13.5°N for the Qaidam Block for the early Carboniferous. Based on global tectonic reconstructions and paleontological evidence, we suggest that the Qaidam Block was adjacent to, but independent from, the North China, South China, Alashan–Hexi and Tarim blocks at this time. This result suggests that Pre-Carboniferous sutures reported around the Qaidam Basin represent collisional events within Gondwana, rather than the final sutures that gave rise to the present tectonic configuration.

1. Introduction

Most Southeast Asian continental terranes originated from the Indian-Western Australian margin of eastern Gondwana. The separation and northward migration of these blocks from Gondwana occurred in three phases that were linked with the successive opening and closure of three intervening Tethyan oceans (Metcalfe, 2013). Following a long history of separation, northward drift and continent accretion, these terranes began to collide during the Late Permian and reached their final configuration within Pangea at the end of the Triassic (Metcalfe, 2006; Rakotosolofo et al., 2006; Stampfli et al., 2013). Several tectonic reconstructions for the Late Paleozoic indicate that the East Asian tectonic blocks were not attached to Pangaea and had a scattered paleogeographic distribution until their convergence in the Early Mesozoic (Scotese, 2001; Metcalfe, 2006, 2011, 2013). Paleomagnetic research that focused on the main tectonic blocks of East Asia, including the North China Block (NCB), the South China Block (SCB), and the Tarim Block, has yielded a complete and reliable Phanerozoic apparent polar wander path (Lin et al., 1985; Zhao and Coe, 1987; Yang et al., 1992, 1998; Yang and Besse, 2001; Wu et al., 1998; Fang et al., 1998; Huang et al., 2000, 2008). However, the tectonic history of smaller yet important Asian terranes remains unclear because of tectonic complexities and insufficient Paleozoic paleomagnetic data. Such data are particularly needed for the Carboniferous, which coincided with the middle part of the northward drift phase of some smaller tectonostratigraphic terranes.

The small Qaidam Basin is located on the northeastern margin of the Qinghai–Tibetan Plateau, and is surrounded by the Tarim, Alashan–Hexi, NCB and Qiangtang blocks (Fig. 1a). The Paleozoic tectonic evolution of this region and relationships between the Qaidam and the surrounding blocks are poorly understood. For example, the spatial–temporal relationship between the Qaidam and Tarim blocks is debated. Heubeck (2001) suggested that the Qaidam, Tarim and Alashan blocks collided and amalgamated before the Middle Devonian. Metcalfe (2006) suggested that the Qaidam Block was originally part of the Tarim Block because of the close similarities of their basement rocks, which consist of Early Proterozoic metamorphic rocks with a Late Proterozoic–Paleozoic sedimentary cover. However, Xu et al. (2011) reported different Late Carboniferous paleolatitudes for these two blocks. The tectonic reconstructions proposed by Cocks and Torsvik (2013) indicate that Tarim Block lay farther to the west of the NCB and SCB, and that the Qaidam Block collided with the NCB after the Devonian. Furthermore, it has been proposed that the Alashan–Hexi Block has been a western extension of the NCB since the Ordovician (Huang et al., 2001). Song et al. (2013) and Xiao et al. (2009) suggested that the Qaidam Block had already accreted to the Alashan/Hexi Corridor terrane by the Late Devonian, whereas Yuan and Yang (2015a) suggested that the Alashan Terrane, which bridged the South Central Asian Orogenic Belt, the Tarim and Qaidam blocks, and the North China

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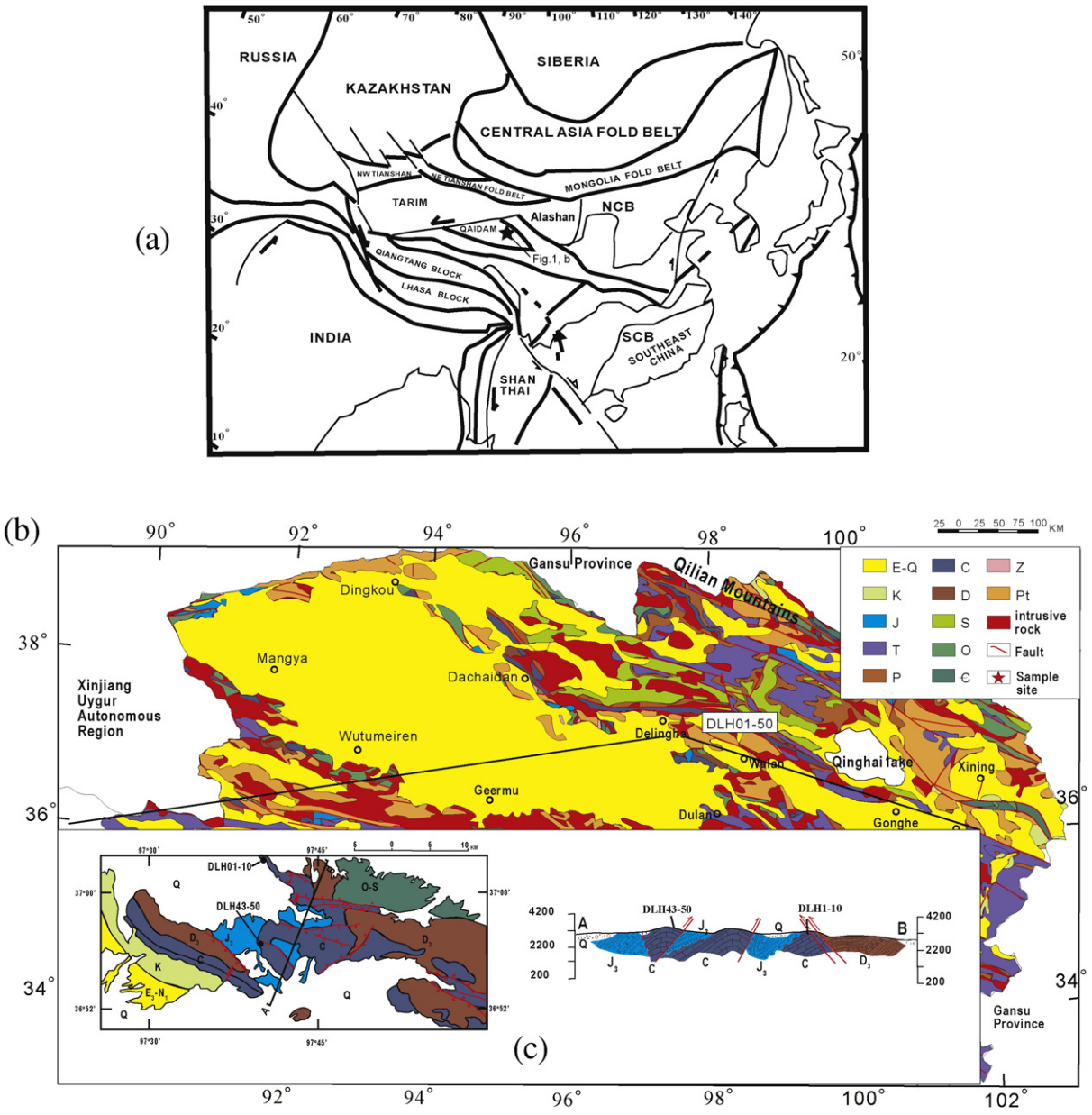

Fig. 1. (a) Simplified tectonic map of China and adjacent area (modified from Yang et al., 1992). The star indicates the sampling location. (b) Structural outline of the Qaidam Basin and its neighboring areas (modified from Ma et al., 2002). (c) Simplified geological map of the sampled location and geological cross-sections through the study area (modified from an unpublished 1:200,000 geological map).

Craton, was not part of North China by the Late Devonian. This small terrane collided with the NCB after the Early–Middle Triassic along a tectonic boundary located between the Helanshan and Zhuozishan mountains (Yuan and Yang, 2015b). Thus, many questions remain about the post-Devonian regional tectonic evolution of Asia, when the continental blocks that presently compose China were drifting northward.

The Qaidam Block is an important geological unit within this broader regional context, and its Paleozoic reconstruction should assist in understanding the evolution of surrounding tectonic belts, the break-up of Gondwana, and the convergence of Pangea. To establish the location of the Qaidam block during the Paleozoic, we carried out paleomagnetic analyses of the Carboniferous strata from the Qaidam Basin.

2. Geological setting

The Qaidam Basin is a small rhomb-shaped basin located on the northeastern margin of the Qinghai–Tibetan Plateau and is surrounded by the Altye, Qilian and Eastern Kunlun mountains. The complex tectonic history of this basin, which involved alternating periods of compressional and extensional tectonics, resulted from its paleogeographic relationship with the surrounding tectonic blocks. The basin is composed of three tectonic units: the Northern Fault Zone, the Central Fold Zone and the Southern Fault Zone. The Northern and Southern Fault zones consist of thrust faults that dip to the south, while the Central Fold Zone is covered by Mesozoic and Cenozoic strata (Chen et al., 2010). Our sampling area is located near Delingha City, and is located on the eastern side of the Central Fold Zone. This region has been subjected to five tectonic events from the Carboniferous to the Cretaceous, as follows: extension during the Carboniferous and Permian, extrusion and uplift during the Triassic, fault-bounded basin formation in the Early to Middle Jurassic, subsidence in the Late Jurassic, and basin inversion during the Cretaceous (Shang et al., 2014). In this area, Carboniferous strata have angular unconformable contacts with overlying Middle Jurassic strata and underlying Late Devonian strata.