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# Multiple 3.8–3.1 Ga tectono-magmatic events in a newly discovered area of ancient rocks (the Shengousi Complex), Anshan, North China Craton

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ABSTRACT

Near Anshan city in the North China Craton, the oldest rocks in Asia ($\geqslant$3300 Ma) have been thoroughly documented at two localities (Baijiafen and Dongshan). In this paper we report the full geological context for more ancient rocks from a third Anshan locality – the polyphase migmatite Shengousi Complex. SHRIMP U–Pb zircon dating indicates a protracted tectono-magmatic history for the Shengousi Complex: The oldest recognised component is banded trondhjemitic gneiss (3773 ± 6 Ma), which is veined by strongly deformed granitic pegmatite. These occur with a second generation of trondhjemitic rocks (3454 ± 8 and 3448 ± 9 Ma). The next generation of plutonic rocks is a composite suite of iron-enriched mafic dykes (3332 ± 6 and 3331 ± 8 Ma) with broadly coeval felsic veins (3311 ± 4 Ma). Finally there was intrusion of monzogranite (3129 ± 6 Ma). Strong deformation has generally brought these 3773–3129 Ma plutonic phases into close concordance to form banded rocks. However, locally cross-cutting relationships are preserved in small lower strain domains, that give a relative chronology agreeing with the absolute zircon U–Pb chronology. All of this complex history is recorded in a single <50 m wide outcrop.

Some of the <3600 Ma rocks of the Shengousi Complex contain 3780–3730 and 3660–3600 Ma inherited zircon xenocrysts. The stronger prominence of 3660–3600 Ma components distinguishes the Shengousi Complex from the Baijiafen and Dongshan complexes, where components of this age are rarer. One possibility is that at 3660–3600 Ma, the Shengousi Complex was at a deeper crustal level than the Baijiafen and Dongshan complexes, and underwent migmatisation at that time.

The $\sim$3450 Ma igneous phases discovered in the Shengousi Complex are new ages for igneous rocks in the Anshan area. The Precambrian geology of the Anshan area is thus marked by polyphase Eoarchaean orthogneisses, the newly recognised $\sim$3450 Ma phases, widespread 3360–3300 magmatic activity, found in association with Mesoarchaean plutonic rocks and the Neoarchaean Anshan Group and Palaeoproterozoic Liaohe Group metasedimentary rocks. This shows that the geology of the Anshan area has a strong similarity with the Narryer Gneiss Complex of Western Australia, which contains the polyphase Eoarchaean Meeberrie gneisses, the 3490–3440 Ma Eurada gneiss association, $\sim$3300 Ma granites and migmatisation, and is intercalated with younger Precambrian metasedimentary rocks of different ages containing Hadean detrital zircons. No other ancient gneiss complexes in the world show such a close match in their history with the Anshan area rocks. This means that the Anshan area is prospective for locating new occurrences of Hadean crustal components intercalated with younger sedimentary rocks.



## 1. Introduction

Rocks older than 3700 Ma have been discovered in only a few areas, such as in Canada (northern Labrador, the Acasta area in the Northwest Territories and Nuvvuagittuq in Quebec; Schiøtte et al., 1989; Bowring et al., 1989; Bowring and Williams, 1999; O'Neil et al., 2007), eastern Antarctica (Black et al., 1986), Greenland (the Itsaq Gneiss Complex; e.g. Moorbath et al., 1973; Baadsgaard et al., 1984; Kinny, 1986; Nutman et al., 1996), Western Australia (Nutman et al., 1991), and around Anshan city in the North China Craton (Liu et al., 1992; Song et al., 1996; Wan et al., 2005).

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Many of the ⩾3450 Ma Anshan gneisses are geochemically anomalous compared to those found elsewhere, with the prominence in Anshan of trondhjemitic rocks with higher $SiO_2$ and lower CaO compared with the tonalites predominating in other ancient terranes. Thus besides the rarity of ancient rocks from scattered localities around the world which provide the only small direct samples of the early Earth, the small occurrences at Anshan are doubly important because they encompass a diversity of protoliths not important in larger >3700 Ma rock occurrences. Thus, discovery of the Shengousi Complex as a third occurrence of >3700 Ma trondhjemitic rocks in the Anshan area is noteworthy, particularly as zircon geochronology also indicates some differences in its post-3700 Ma crustal evolution compared with the already documented Anshan area Dongshan and Baijiafen complexes (Liu et al., 1992; Song et al., 1996; Wan et al., 2005).

In this paper, we report field relationships and SHRIMP U–Pb zircon ages for rocks in a single ~50 m-long continuous exposure of the Shengousi Complex. The results indicate that even on a scale of a single outcrop, there is a protracted record of magmatic activity. Such a scenario is noted in other ancient gneiss complexes (e.g. parts of the Itsaq Gneiss Complex, Nutman et al., 2000; and all of the Acasta gneisses; Iizuka et al., 2007). We record the presence of ~3450 Ma igneous phases in the Shengousi Complex, a magmatic age previously not recognised in the Anshan area. The full Precambrian history of the Anshan area, from the old Eoarchaean gneiss components to intercalation with low metamorphic grade Palaeoproterozoic sedimentary rocks shows a very close similarity to the history of the Western Australia Narryer Gneiss Complex and its intercalated younger Precambrian metasedimentary rocks. Implications for this will be discussed.

## 2. Regional Anshan geology

The Archaean geology of the North China Craton (NCC) is dominated by 2550–2500 Ma plutonic rocks of diverse origins with associated volcanic and sedimentary rocks, including major bodies of banded iron formation (Wang et al., 1990; Zhao et al., 2002, 2008; Kröner et al., 2005; Wilde et al., 2005; Wan et al., 2011a; Nutman et al., 2011; Zhai and Santosh, 2011). Anshan in Liaoning Province is the only area where >3700 Ma rocks have been identified. The >2900 Ma rocks in the Anshan area are: ~3810 Ma Baijiafen banded trondhjemitic rocks (biotite-bearing siliceous gneisses rich in sodic plagioclase), ~3790 Ma quartz diorite gneisses at Dongshan, ~3800 + 3300 Ma migmatites at Dongshan, the 3360 Ma Chentaigou supracrustal rocks, ~3300 Ma Chentaigou granite, 3140–3120 Ma Lishan trondhjemite, 3000 Ma Dong'anshan granite and 3000–2900 Ma Tiejiashan potassium-rich granite (Fig. 1; Liu et al., 1992, 2007, 2008; Song et al., 1996; Wan et al., 1997, 1998, 1999, 2001, 2002a, 2002b, 2005; Yin et al., 2006; Nutman et al., 2009a; Zhou et al., 2007, 2009). Additionally, Wu et al. (2008) identified ~3865 Ma zircon xenocrysts in ~3300 Ma plutonic rocks. The >2900 Ma rocks were overlain by the ~2500 Ma Anshan Group of volcano-sedimentary rocks rich in banded iron formation and were then intruded by large volumes of ~2500 Ma Qidashan syenogranite (Song et al., 1996; Wan et al., 2011b). Archaean metamorphic grade is everywhere amphibolite facies, with neither relict orthopyroxene nor textural evidence (such as blebby texture – pseudomorphs of biotite ± hornblende after pyroxene; McGregor and Friend, 1997) that would indicate any episodes of granulite facies metamorphism in the area. The Anshan area Archaean complex was then disrupted by Palaeoproterozoic shear zones with local greenschist facies metamorphism and was intercalated with Palaeoproterozoic supracrustal rocks (Luo et al., 2004; Wan et al., 2006). Thus the >3000 Ma rocks occur as discontinuous bodies scattered throughout the Anshan area. Additionally, in the Anshan area, large

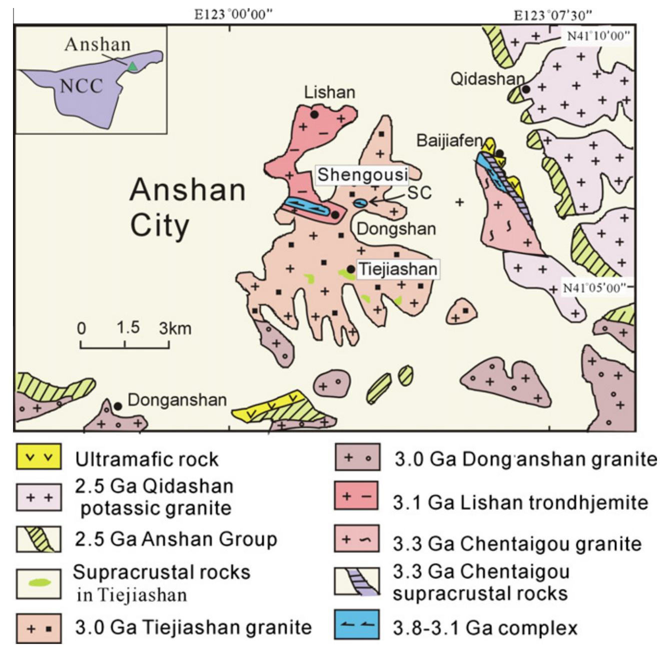


**Fig. 1.** Geological map of the Anshan area showing distribution of the Baijiafen, Dongshan and Shengousi complexes (after Wan et al., 2005). SC = Shengousi Complex. The inset (top left) shows location of the Anshan area in northeastern China.

areas of recent deposits cover the bedrocks. Therefore the search for more >3700 Ma rocks is not simple, and to a certain extent relies on serendipity.

## 3. Analytical methods

For whole rock analysis, samples were crushed to 200-mesh size for analysis. Major oxides, together with trace elements and REE were analysed by XRF and ICP-MS at the Institute of Geological Analysis, Chinese Academy of Geological Sciences. Uncertainties depend upon the concentration in the sample, but generally for XRF and ICP-MS are estimated at ±3–5% and ±3–8%, respectively. The whole rock geochemical analyses are presented in Table 1 and are summarised in Appendix A.

Zircon separation and U–Pb dating were carried out at the Beijing SHRIMP Center, Chinese Academy of Geological Sciences, Beijing. The SHRIMP II analytical procedure has been described by Williams (1998). The intensity of the primary $O^{2-}$ ion beam was 4–5 nA and primary beam size was ~30 μm. Each analytical site was rastered for 2–3 min prior to analysis to remove any common Pb on the surface. Five scans through nine mass stations were made for each analysis. Standards used were SL13, with U content of 238 ppm, and TEMORA 1, with a $^{206}Pb/^{238}U$ age of 417 Ma (Williams, 1998; Black et al., 2003), provided by the Australia National University. Data processing was carried out using the SQUID and ISOPLOT programs (Ludwig, 2001), applying the $^{204}Pb$ correction based on the measured values. $^{207}Pb/^{206}Pb$ ages are used for all data because of all the zircons being of Archaean age. Uncertainties for individual analyses are quoted at the 1 sigma level, whereas errors for weighted mean ages are quoted at 95% confidence.

## 4. Shengousi Complex

### 4.1. General characteristics

The Shengousi Complex examined in this paper is located between the Dongshan and Baijiafen complexes where >3700 Ma