

Timing of Magmatism and Metamorphism in the Mashan Complex of NE China: a Consequence of a Siberian or a Late Pan-African Gondwanan Collision?

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The Mashan Complex, located within the Jiamusi Massif in the eastern part of Heilongjiang Province, northeastern China, is a sequence of tectonically-interleaved ortho- and paragneisses and associated granitoids. Three main outcrop areas have been identified (Fig. 1), showing a northward decrease in metamorphic grade from granulite to amphibolite facies (Cao et al., 1992). The granulite facies metasedimentary rocks in the southern area around Ji Xi are a khondalitic sequence of graphite, sillimanite and cordierite-bearing gneisses, carbonates and felsic paragneisses, characterised by a tight clockwise P-T path, with peak temperatures of up to 850°C and pressures of 7.4 kbar (Jiang, 1992). Amphibolite facies rocks predominate in the central and northern outcrops (Fig. 1) and are characterised by peak temperatures of ~650°C with pressures of 6-7 kbar (Cao et al., 1992). The metamorphic pattern has been attributed to magmatic underplating accompanying post-peak lithospheric delamination (Wilde et al., 1999). Rapid cooling and decompression, suggested by various retrograde textures, favours a combination of exhumation and tectonic denudation, with delamination leading to rapid uplift and extensional collapse.

Recent U-Pb zircon geochronology (Wilde et al., 1997, 1999, 2000, 2003) has established a ~500 Ma age for metamorphism in the area. This age is recorded in both the khondalitic paragneisses and in the tectonically-interleaved sheets of orthogneiss; indeed, all samples so far analysed (n = 10), including the associated granitoids, record this event. Some samples of khondalite also contain concordant zircon populations at ~700 Ma, ~900 Ma, ~1050 Ma, ~1300 Ma, ~1600 Ma and ~1900 Ma, interpreted to represent detrital grains incorporated from Neo-, Meso- and Palaeoproterozoic source rocks. One sample of orthogneiss from near Liu Mao also contains older zircon cores, with a spread of ages from 530 Ma to 1274 Ma. These older ages reflect formation of the igneous dioritic protolith at ~1275 Ma, variously disturbed by the ~500 Ma granulite facies metamorphic event.

New zircon data (Wilde et al., 2003) from variably-deformed granitoids associated with the Mashan Complex in the middle and northern outcrops (Fig. 1), indicate they are not Palaeoproterozoic in age, as initially suggested (Zhao et al., 1995), but are instead early Cambrian, with igneous ages ranging from ~515 Ma to ~530 Ma. They provide the first evidence of late Pan-African igneous events in NE China, being only slightly older than peak metamorphism. There was thus only a short time period between generation of granitoids and the onset of regional metamorphism.

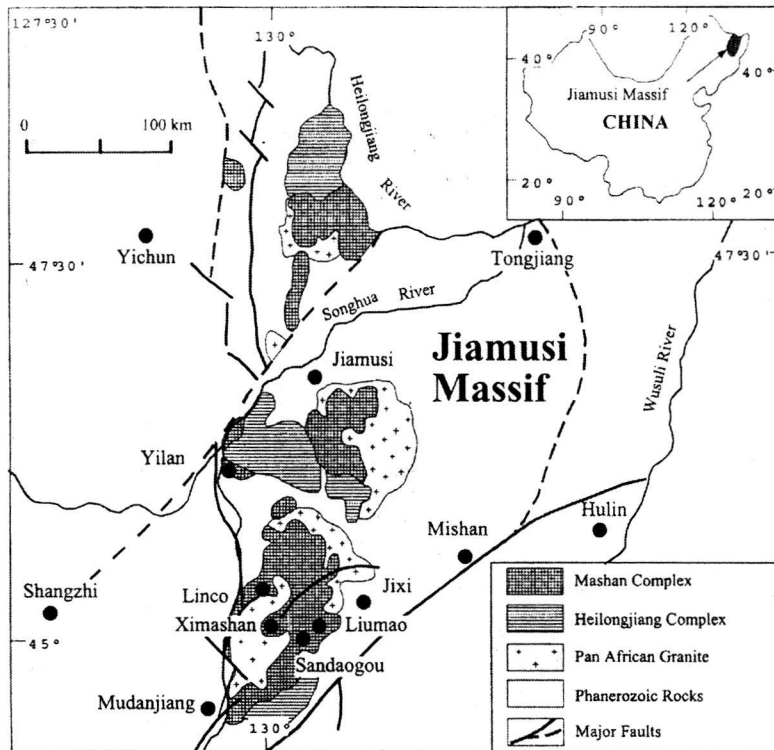


Figure 1. Distribution of rocks within the Jiamusi Massif, NE Chin (modified from Wilder et al., 2000).

The question of which continental blocks may have been involved in the ~500 Ma collisional event is an intriguing one. The Jiamusi Massif is currently located between the North China and Siberian Cratons, within the Central Asian Orogenic Belt, and these two blocks are the obvious ones to consider first. Recently, Salnikova et al. (1998) have reported single-grain zircon $^{206}\text{Pb}/^{238}\text{U}$ ages of 488 ± 0.5 Ma for trondhjemites emplaced during granulite facies metamorphism of the Sludyanskiy Complex at the southern margin of the Siberian Craton, with peak metamorphism determined at 478 ± 2 Ma. These authors consider that this high-grade Palaeozoic metamorphic terrain extends for more than 1000 km along the southern margin of the Siberian Craton. The ages reported from this terrain are only slightly younger than the dates from the Mashan Complex and it is possible they may be related to the same general event. It has previously been considered that the Jiamusi Massif may continue north to link with the Burya Massif in Siberia (Wilde et al., 1997) and it may be that these two blocks came together during the Cambro-Ordovician - rather than in the late Jurassic, when the other Chinese blocks are believed to have collided with Siberia (Zhao et al., 1996).

Alternatively, the Jiamusi Massif may have been involved in a collision with one of the other Gondwanaland fragments during the Pan-African orogeny. Reconstructions by Li et al. (1996) and Zhao et al. (1996) show a close spatial association between the North China, South China and Tarim Blocks from about 520 Ma to the Late Jurassic, when amalgamation of these three units with Siberia occurred. Their data suggest that all these blocks had a close affinity to the Gondwanaland continents, being located off the northern coast of Australia. If the Jiamusi Massif collided with the North China

Craton at ~500 Ma, then it too would be located along the edge of the Gondwanaland supercontinent. In favour of a Gondwanaland/Pan-African association is that all terrains showing broadly similar late Pan African metamorphic P/T conditions, and also containing khondalitic metasediments, can be closely grouped together, including parts of East Antarctica, Western Australia, Sri Lanka and India, and possibly including regions in Madagascar, Tanzania and Kenya. One problem with this argument is that ages for peak metamorphism in these late Pan-African terranes are commonly ~50 Ma older than those recorded from the Mashan Complex. However, exceptions to this are the Prydz Bay area of Antarctica, where dates of 515-490 Ma have been reported (Kinny et al., 1993; Henson and Zhou, 1995) and in the Delamerian Orogen in South Australia, where SHRIMP U-Pb igneous zircon ages of 514 ± 5 Ma and metamorphic ages of 503 ± 7 Ma have recently been reported (Foden et al., 1999).

The Delamerian Orogeny resulted from convergence along the eastern and southern margins of the Gawler Craton. Interestingly, inherited cores in zircons from the Rathjen Gneiss show peak concentrations at 675-550 Ma, 1000-900 Ma, and ~1250 Ma (Foden et al., 1999), similar to populations identified from the Mashan Complex paragneisses. Slightly younger ages of 490-480 Ma have also been recorded from post-tectonic granitoids in the Adelaide Fold-Thrust Belt (Turner and Foden, 1996) - showing a close similarity to the Siberian margin data of Salnikova et al. (1998). However, Siberia is considered to have been located further to the east in the initial Rodinia configuration (Dalziel, 1991), in close association with Laurentia, and by ~540 Ma it is considered to lie much further to the southeast, so that a close association with the Chinese blocks appears unlikely.

Until recently, the main problems in correlating the Delamerian Orogen with the Mashan Complex were the lack of slightly older igneous ages in the latter and the restriction of the Delamerian Orogen to southern Australia and its southward extension into the Ross Orogen of Antarctica. New data showing that igneous rocks associated with the Mashan Complex crystallised between ~515 Ma and ~530 Ma (Wilde et al., 2003) remove the first objection, whereas recent U-Th-Pb chemical dating of zircon and monazite by Watanabe et al. (2001) indicates that ~500 Ma events are recorded in the Halls Reward metamorphic belt in Queensland, suggesting the possibility that the Delamerian Orogen may extend into northern Australia. If this is substantiated, the location of the Jiamusi Massif off northern Australia, along with the other Chinese blocks at ~500 Ma (Li et al., 1996; Zhao et al., 1996; Wilde et al., 1999), seems a possibility.

The development of granitic rocks in the Jiamusi Massif 15-30 million years prior to peak metamorphism may indicate that the block lay on the subduction-side of a collisional orogen. Whether this involved Siberia, North China, or some other block located to the north of Australia at ~500 Ma, cannot be resolved at present, since there are no reliable palaeomagnetic data. Thus the exact location of the Mashan Complex and co-existing components of the Jiamusi Massif at ~500 Ma remains unknown.

References

- Cao, X., Dang, Z.X., Zhang, X.Z., Jiang, J.S. and Wang, H.D., 1992. Jiamusi Composite Terranes. Jilin Publishing House of Science and Technology, Changchun, 224 p. (in Chinese, with English and Russian abstracts).
- Dalziel, I.W.D., 1991. Pacific margins of Laurentia and East Antarctica-Australia as a conjugate rift pair: evidence and implications for an Eocambrian supercontinent. *Geology*, 19, 598-601.

- Foden, J., Sandiford, M., Dougherty-Page, J. and Williams, I., 1999. Geochemistry and geochronology of the Rathjen Gneiss: implications for the early tectonic evolution of the Delamerian Orogen. *Australian Journal of Earth Sciences*, 46, 377-389.
- Hensen, B.J. and Zhou, B., 1995. A Pan-African granulite facies metamorphic episode in Prydz Bay, Antarctica: evidence from Sm-Nd garnet dating. *Australian Journal of Earth Sciences*, 42, 249-258.
- Jiang, J., 1992. Peak regional metamorphism of the khondalite series of Mashan Group and its evolution. *Acta Petrologica et Mineralogica*, 11, 97-108 (in Chinese with English abstract).
- Kinny, P. D., Black, L. P. and Sheraton, J. W., 1993. Zircon ages and the distribution of Archaean and Proterozoic rocks in the Rauer Islands, Antarctic Science, 5, 193-206.
- Li, X., Zhang, L. and Powell, C.Mc., 1996. Positions of the East Asian cratons in the Neoproterozoic supercontinent Rodinia. *Australian Journal of Earth Sciences*, 43, 593-604.
- Salmikova, E.B., Sergeev, S.A., Kotov, A.B., Yakovleva, S.Z., Steiger, R.H., Reznitskiy, L.Z. and Vasilev, E.P., 1998. U-Pb zircon dating of granulite metamorphism in the Sludyanskiy Complex, eastern Siberia. *Gondwana Research*, 1, 195-205.
- Turner, S.P. and Foden, J.D., 1996. Magma mingling in late-Delamerian A-type granites at Mannum, South Australia. *Mineralogy and Petrology*, 56, 147-169.
- Watanabe, T., Nishiya, T., Yokoyama, K., Kuramoto, Y. and Saito, K., 2001. Archean detrital zircons from the Early Paleozoic Halls Reward Metamorphic rocks, North Queensland, Australia. In: Sklyarov, E.V., (ed.), *Assembly and Breakup of Rodinia Supercontinent: Evidence from South Siberia IGCP 440 Irkutsk Meeting 2001, Guidebook and Workshop*, Russian Academy of Sciences, 191.
- Wilde, S.A., Dorsett-Bain, H.L. and Liu, J., 1997. The identification of a Late Pan-African granulite facies event in northeastern China: SHRIMP U-Pb zircon dating of the Mashan Group at Liu Mao, Heilongjiang Province, China. *Proceedings of the 30th International Geological Congress, Beijing*, 17, VSP International Science Publishers, Amsterdam, 59-74.
- Wilde, S.A., Dorsett-Bain, H.L. and Lennon, R.G., 1999. Geological setting and controls on the development of graphite, sillimanite and phosphate mineralisation within the Jiamusi Massif: an exotic fragment of Gondwanaland located in North-Eastern China? *Gondwana Research*, 2, 21-46.
- Wilde, S.A., Zhang, X.Z. and Wu, F.Y., 2000. Extension of a newly-identified 500 Ma metamorphic terrain in North East China: further U-Pb SHRIMP dating of the Mashan Complex, Heilongjiang Province, China. *Tectonophysics*, 328, 115-130.
- Wilde, S.A., Wu, F.Y. and Zhang, X.Z., 2003. Late Pan-African Magmatism in Northeastern China: SHRIMP U-Pb zircon evidence for igneous ages from the Mashan Complex. *Precambrian Research*, (in press).
- Zhao, C., Peng, Y. and Dang, Z., 1995. The formation and evolution of crust in Eastern Jilin and Heilongjiang Provinces. *Geotectonic Map of Eastern Jilin and Heilongjiang Provinces, 1:1,500,000 scale map and explanatory notes*. Shenyang Institute of Geology and Mineral Resources and Heilongjiang Institute of Geology and Mineral Resources.
- Zhao, X.X., Coe, R.S., Gilder, S.A. and Frost, G.M. 1996. Palaeomagnetic constraints on the Palaeogeography of China: Implications for Gondwanaland. *Australian Journal of Earth Sciences*, 43, 643-672.