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▶ **To cite this version:**

Michel Faure, Wei Lin, Yan Chen. Is the Jurassic (Yanshanian) intraplate tectonics of North China due to westward indentation of the North China block?. Terra Nova, 2012, 24 (6), pp.456-466. 10.1111/ter.12002 . insu-00724642

HAL Id: insu-00724642
https://insu.hal.science/insu-00724642

Submitted on 22 Aug 2012

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Is the Jurassic (Yanshanian) intraplate tectonics of North China due to westward indentation of the North China Block?

Michel Faure [1], Wei Lin [2], Yan Chen [1]

1: Université d'Orléans, Institut des Sciences de la Terre d'Orléans, UMR 7327, 1A Rue de la Férollerie, 45071 Orléans Cedex 2, France

2: State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China

ABSTRACT The northern mountains of Beijing are the type locality of the Mesozoic Yanshanian orogen. Our structural study emphasizes the importance of dextral strike-slip for the formation of this intracontinental belt. The South- and North-directed thrusts are positive flower structures rooted in strike-slip faults. This transpressional tectonics developed from Late Triassic to Late Jurassic-Early Cretaceous through three deformation phases coeval with syntectonic sedimentation, separated by two transtensional episodes coeval with magmatism. The Late Jurassic–Early Cretaceous tectonic event is also recognized in several places of North China. Strike-slip faulting controls the deformation of the northern border of the North China block in the Yanshan-Yinshan belt. Simultaneously, East-directed thrusts and folds develop along N-S elongated ranges in Helanshan, Shanxi highlands and Taihangshan. The Jurassic tectonics of the North China Block is interpreted in a unitary way as the result of the westward underthrusting of the North China block below the Alashan block.

Introduction

The mechanisms of intracontinental orogeny have long been discussed, since intraplate mountain belts cannot be ascribed to the plate margin interaction paradigm that assumes that the interior of a continent is rigid and hard to deform. It is well accepted that the deformation of the continental crust can be a far-field consequence of subduction or collision, as exemplified by the North American Laramide belt or Indian collision (e.g. Avouac et al, 1993; English and Johnston, 2004).

From studies in the Yanshan range north of Beijing, Wong (1927) defined the Mesozoic “Yanshanian movement”. Subsequently, the term “Yanshanian” was used to account for the Mesozoic deformations in the entire China (e.g. Wong, 1929; Huang, 1978, Yang et al., 1986). Since nearly 80 years, “Yanshanian” depicts the Jurassic-Cretaceous time interval, rather than a specific tectonic event developed in the North China Block (NCB). This loose use led to confusion since contemporaneous events are not necessary related to the same geodynamic cause.

The Yanshanian movement corresponded initially to a set of Jurassic-Cretaceous tectonic phases (Wong, 1929). It is now acknowledged that a major break took place in early Cretaceous (ca 136 Ma). Since this time, the NCB experienced a widespread NW-SE extension recorded by brittle and ductile normal faults, synsedimentary half grabens filled by continental red beds, and synkinematic plutons (e.g. Zheng et al., 1988; Davis et al., 1996; 2002; Meng, 2003; Liu et al., 2005; Lin and Wang, 2006, Lin et al., 2007, 2008; Charles et al., 2010). Although the timing and modalities of extension are well acknowledged in East Asia, the geodynamic mechanisms are still disputed. Post-orogenic collapse, roll-back of the subducting Palaeopacific slab, mantle lithosphere foundering or delamination due to asthenospheric convection are the most invoked processes (see Lin and Wang, 2006 for a discussion of these models). The pre-136 Ma tectonics, or Yanshanian tectonics *stricto sensu,* remains poorly understood. Most of authors acknowledge an intracontinental evolution accommodated by N-S contraction (e.g. Zhao, 1990; Zheng et al., 1998; He et al., 1999; Davis et al., 2001; Hu et al., 2010). However, the architecture, kinematics, timing, and geodynamics of the Yanshan orogeny are not well explained yet. This paper presents the architecture of the Yanshan range northeast of Beijing (Figs. 1, 2).   The analysis of Jurassic deformations in other areas of the NCB allows us to propose a new tectonic interpretation of the Yanshan orogeny driven by westward indentation of the NCB below the Alashan block.

Polyphase Tectonics of the Yanshan area

The Yanshan range that develops NE of Beijing is a part of the 1000 km long, E-W striking, Yanshan-Yinshan belt. Numerous geological studies provide a general lithostratigraphic and tectonic outline of the Yanshan area. The Archean basement shaped up by a Paleoproterozoic orogeny (HBGMR, 1989; Kusky and Li, 2003; Kusky et al., 2007; Zhao et al., 2005; Faure et al., 2007; Trap et al., 2007; in press) was overlain by a thick Meso to Neoproterozoic sedimentary cover of terrigeneous and carbonates rocks. The Cambrian-Ordovician platform carbonate rocks were partly eroded during the Devonian emersion (Wang et al., 2010). Since the Late Palaeozoic, continental deposits are dominant. The Triassic, Jurassic, and Cretaceous formations consist of sandstone, siltstone and conglomerate. This detrital sedimentation, represented by chaotic deposits with disrupted and slumped layers, and olistoliths, argues for a syn-tectonic setting. Due to the scarcity of fossils, the stratigraphic record is imprecise, but radiometric dating of interbedded lava flows provides some time constraints. The Zhangjiakou and Tiaojishan formations are now dated at 133±3 Ma, and 156±3 Ma, respectively (Liu et al., 2006, Fig. 3).

The Palaeoproterozoic Fengning-Longhua fault, which is the northern boundary of the Yanshan belt is reworked as a brittle dextral fault along which Mesoproterozoic rocks are placed to vertical (Fig. 4A). In the study area, the main Yanshanian deformations are concentrated between Chengde and Banbishan (Fig. 1). Along a North-South profile, the Chengdeshi, Pingquan-Gubeikou, Gubeikou, Xinglong, and Banbishan thrusts are the most important structures, but several second order faults are also mapped (HBGMR, 1989; Zhao 1990, Chen, 1998; Davis et al., 1998, 2001; Fig. 1).

The section from Chengdeshi to Kuancheng is analyzed below as an example of the architecture of the Yanshan belt (Fig. 2A). A “Chengde thrust” has been proposed as a large allochthonous nappe displaced from South to North for more than 40km, and rooted in the Xinglong thrust (Davis et al., 1998, 2001). This interpretation is disputed (He and Niu, 2004;

Liu et al., 2007). Our observations also do not support the view of a large overthrust, as in the footwall of the inferred nappe neither the Proterozoic sandstone nor the Jurassic volcanic and sedimentary rocks are deformed. For instance, sedimentary features are perfectly preserved in the Proterozoic sandstone (Fig. 5A). Furthermore, the geological map (HBGMR, 1989), and our field survey shows that Archean metamorphic rocks would belong to this speculated nappe. Such a structure is unlikely for a thin-skinned allochthon. A north-directed high-angle fault, called here Chengdeshi thrust (in order to avoid confusion), is a more realistic geometry than a large thin-skinned nappe. The Chengdeshi high-angle thrust is reworked by a Cretaceous normal fault that controls the sedimentation in the Chengde basin.

South of Chengde, Late Triassic sandstone and siltstone are folded and cleaved along the South-directed Pingquan-Gubeikou thrust (Zhao, 1990, Davis et al., 2001; Fig. 6D). In the thrust footwall, Palaeozoic rocks are deformed in a brittle way. Open folds, tension gashes and cracks are widespread, and still indicate a southward displacement. To the South, the brittle, high-angle Goubeikou thrust superposes Neoproterozoic rocks above Late Jurassic red beds (Fig. 4B). Lastly, SE of Kuancheng, a series of SE-directed thrusts merge into a single dextral strike-slip fault exposed between Xinglong and Banbishan (Fig. 1). The Banbishan thrust (Chen, 1998) appears as a combination of thrusting and folding, corresponding to a positive flower structure (Zhang et al., 2001; Fig. 7A, B, C). Between Banbishan and Kuancheng,km-scale, SE-verging recumbent folds are well developed (Fig. 5B, C). The SE-vergent folds exhibit an axial planar slaty cleavage (Fig. 6C). A western cross-section (Fig. 2B) shows the extension of the Gubeikou thrust, and documents the north-directed Xinglong thrust (Chen, 1998) that becomes vertical southward, and roots into a dextral strike-slip fault (Zhang et al., 1998; Fig. 8C).

The deep domain of the Yanshan belt is exposed to the west of the study area (Fig. 1). Due to the SE displacement along the Shuiyu extensional shear zone, the footwall exposes Mesozoic granitoids and metamorphic rocks. The S-directed Shihetang thrust involves the synkinematic Yunmengshan granodiorite (Davis et al., 1996; Wang et al., 2011; Figs. 2C; 7D).

To the north, a vertical fault separates the Archean basement from a Jurassic continental basin. Along the fault, drag-folds, with subvertical axes, and asymmetric lenses indicate a dextral strike-slip movement (Figs. 6A, B; 8A).

In summary, the structure of the Yanshan belt is characterized by a network of moderate to high-angle thrusts connected with dextral strike-slip faults. Although rarely recognized in the previous works (Zhang et al., 1998; 2001), fault planes with subhorizontal striae, sigmoidal lenses, and drag folds with vertical axes are widespread. Conversely to a classical fold-and-thrust belt, in the Yanshan area, the thrusts are not organized with a clear polarity as both north and south directed thrusts are recognized. The importance of belt-parallel strike-slip faults has been underestimated in the previous structural studies (Zhang et al., 2001).

Time Constraints

Five tectonic, magmatic and sedimentary events (D_0 to D_4, Fig. 3) are recognized in the Yanshan area. The peraluminous Dushan granite, emplaced at 223±2 Ma (Luo et al., 2003), results of a post-orogenic crustal melting. Thus a Middle Triassic D_0 event is inferred but its tectonic setting is not understood yet. Late Triassic South-verging folds along the Pingquan-Gubeikou thrust document a D_1 event (Zhao, 1990; Davis et al., 2001). The Triassic clastic rocks are syntectonic deposits supplied by a rising and eroding relief located to the north. The D_1 structures are unconformably covered by Early Jurassic (196-184 Ma) conglomerate, sandstone, basalt and andesitic volcanic rocks (HBGMR, 1989) that represent the post-D_1 molasse. Several granitic intrusions dated at ca. 175-172 Ma (Luo et al., 2001) post-date the D_1 event that occurred in Late Triassic.

The D_2 event is characterized by the N-NW directed Chengdeshi and Xinglong thrusts. The 165-155 Ma volcanic and terrigeneous rocks (Tiaojishan formation) that unconformably cover these north-directed thrusts represent the D_2 molasse. Several dioritic and granodioritic plutons, emplaced at ca 160-150 Ma, post-date the D_2 event.

The D_3 event is the most developed one. South of Chengde, the Gubeikou and Banbishan strike-slip-thrust systems formed in superficial conditions. To the east, NW of Miyun, top-to-the south ductile shearing is developed in metamorphosed country rocks. The D_3 Shihetang shear zone is dated at 143±3 Ma by the syntectonic Yunmengshan granodiorite (Davis et al., 1996, Wang et al., 2011).

After 136 Ma, in late Early Cretaceous, the syntectonic deposition of the terrigeneous Zhangjiakou formation in half grabens, such as the Luanping or Chengde basins, represents the D_4 event. The D_4 ductile and brittle normal faults developed in an area wider than the Yanshan belt, as Mongolia, S. Siberia, and South China are also involved (e.g. Meng, 2003; Donskaya et al., 2008, Lin et al., 2008; Daoudene et al., 2009). The D_4 extensional tectonics is not a direct consequence of the Jurassic Yanshan orogeny. Conversely, the D_1, D_2, and D_3 events described here are representative tectonic phases for the evolution of the Yanshan orogeny. Among these events, D_3 is the most widespread one, responsible for the main structures of tfhe Yanshan belt.

Jurassic Tectonics in the North China Block

Mesozoic deformations distribute in narrow belts around or within the NCB (Fig. 9). In the *Yinshan area*, N-NW directed Middle and Late Jurassic thrusts with an estimated displacement of ca 30km are exposed in the Daqingshan (Zheng et al., 1998; Darby et al., 2001; Darby and Ritts, 2007). To the West of Baotou, along the southern margin of the Yinshan belt, S-directed Late Jurassic high-angle thrusts are recognized (Liu et al., 2004). The Daqingshan and S. Yinshan nappes can be correlated to the D_2 and D_3 events, respectively. An early Jurassic synsedimentary extension (Ritts et al., 2001) predates the D_2 event. In *Western Ordos,* km-scale Late Jurassic East-directed imbricated thrusts and folds are exposed in the Helanshan and surrounding ranges (Teilhard de Chardin and Licent, 1924; Wong, 1929; Zheng et al., 1998; Liu et al., 2000; Darby and Ritts, 2002; Zhang et al., 2007; Fig. 4C). A decollement layer separates the folded and thrusted Palaeozoic series from the underlying Ordos basement (Zhang et al., 2007). The N-S trending *Shanxi highlands* and *Taihangshan ranges* that bound the Ordos basin from the North China Plain are characterized by thin-skin tectonics. The Late Jurassic East-directed thrusting and folding is accommodated at depth by a decollement layer (Zhang et al., 2008).

The *Qinling-Dabie belt* represents the southern margin of the NCB. In the northern side of the chain, NE-SW striking folds deform the Palaeozoic rocks, and locally metamorphic rocks overthrust to the North the Middle Jurassic formations (Zhang et al., 2008). This structure complies with a Late Jurassic NW-SE shortening. The age of this deformation is not settled yet as the thrusting occurred in upper crustal level, and most of the Mesozoic formations are buried beneath the Cenozoic deposits. Along the *Tan-Lu fault* (TLF), hornblende and phengite $^{40}Ar/^{39}Ar$ ages of 198-181 Ma, 162-155 Ma, 143-139 Ma (Zhu et al., 2005, 2009; Wang, 2006) argue for several thermal episodes close in time to the D_1, D_2, and D_3 events, respectively. Strike-slip faulting was completed before Late Triassic (Zhu et al., 2009). During the Jurassic extensional and compressional phases are recognized in the Hefei basin (Zhao et al., 2000). A Jurassic N150E maximum principal stress ($\sigma1$) direction has been computed from fault analysis (Vergely et al., 2007; Mercier et al., 2007). This NW-SE shortening is similar to the one inferred from dextral faulting in the Yanshan area. East of the TLF, in Shandong peninsula, a NW-SE stretching, coeval with the emplacement of the Late Jurassic Linglong pluton dated at 160-150 Ma (Charles et al., 2010), supports an extensional regime for the TLF before the D_3 event.

Discussion and Conclusion

In the Yanshan-Yinshan belt, northwestward or southeastward thrusts are rooted into E-W striking dextral strike-slip faults. These thrust sheets can be interpreted as positive flower structures resulting of several transpressional phases (D_1, D_2, D_3) separated by transtensional episodes during which sedimentation and volcanism developed in narrow East-West elongated basins. An along strike dextral strike-slip shearing accounts well for this structural pattern.

The eastward displacement along the western border of the Ordos basin, the Shanxi highlands and Taihangshan is coeval with the dextral strike-slip recorded in the Yanshan-Yinshan belt. Conversely to other places of North China, the Late Jurassic tectonics of eastern Shandong is extensional, but still controlled by an E-W to NW-SE stretching direction.

Although apparently unrelated, all these contemporaneous tectonic features can be interpreted in a unitary way. In terms of finite strain, the E-W to NW-SE direction appears to control the Jurassic structural evolution of NCB. Along the Yanshan-Yinshan belt, dextral shearing accommodated the deformation, whereas in Helanshan, and central part of NCB, east directed folding and thrusting are coeval with the E-W shortening. The basal decollement that separates the deformed sedimentary cover from the Precambrian basement implies that the NCB was underthrusted to the West below the Alashan block (Fig. 10). During this displacement, the NCB did not behave as a rigid block. Compression occurred in Shanxi highlands, and Taihangshan, and extension in eastern Shandong. Ancient faults nearly perpendicular to the maximum stretching, (e.g. Tan-Lu fault), were reworked with a normal component. It is worth to note that the Shanxi highlands, and Taihangshan are located in areas where Palaeoproterozoic deformation is important (e.g. Zhao et al., 2005; Faure et al., 2007; Trap et al., 2011). These inherited structures might have played a role in localizing the Jurassic deformation. Modeling of the Late Jurassic stress field of the NCB indicates a NW-SE strike of $\sigma 1$ that complies with our interpretation (Hou et al., 2010).

The Jurassic tectonics in the Yanshan-Yinshan belt was interpreted as a far-field effect of the Mongol-Okhotsk collision (He et al., 1998; Davis et al., 2001; Darby et al., 2002). Alternatively, a far-field effect of the collision of the Lhasa block with Asia was considered as the cause of the deformation in Ordos area (Dong et al., 2008; Zhang et al., 2008). The deformation in eastern NCB has been viewed as a consequence of the Palaeopacific subduction (Zhu et al., 2005, 2009). All these three geodynamic causes are possible, but detail structural and chronological constraints are too rare to settle a definite conclusion.

In spite of an apparent heterogeneity, the Jurassic, i.e. Yanshanian, deformations of the NCB can be interpreted in their entirety as a consequence of the westward underthrusting of the NCB below the Alashan block. At the lithophere scale, the geodynamic cause of the Yanshan orogeny of North China remains an open question. Nevertheless, this Jurassic tectonics is unrelated to the late Early Cretaceous extension widespread in eastern Eurasia.

Acknowledgements

This work has been supported by NSFC Project 40872142, and Chinese National 973 Project No 2009CB825008.

References

Avouac, J. P., Tapponnier, P., Bai, M., You, H. and Wang, G., 1993. Active thrusting and folding along the Northern Tien Shan and Late Cenozoic Rotation of the Tarim relative to Dzungaria and Kazakhstan. *J. Geophys. Res.*, **98(B4),** 6755-6804,doi:10.1029/92JB01963.

Charles, N., Gumiaux, C., Augier, R., Chen, Y., Lin, W. and Zhu, R., 2010. Metamorphic Core Complex vs. Synkinematic pluton in continental extension setting: Insights from key structures (Shandong Province, eastern China). *J. Asian Earth Sci.*, **40**, 261-278, doi:10. 1016/j. jseaes. 2010. 07. 006.

Chen, A., 1998. Geometric and kinematic evolution of basement-cored structure: Intraplate orogenesis within The Yanshan Orogen, North China. *Tectonophysics*, **292**, 17-42.

Daoudene, Y., Gapais, D., Ledru, P., Cocherie, A., Hocquet, S. and Donskaya, T., 2009. The Eerendavaa Range (north-eastern Mongolia): an additional argument for Mesozoic extension throughout eastern Asia. *Int. J. Earth Sci*., **98**, 1381-1393.

Darby, B.J. and Ritts, B.D., 2002. Mesozoic contractional deformation in the middle of the Asian tectonic collage; the intraplate Western Ordos foldthrust belt, China. *Earth Planet. Sci. Lett.*, **205**, 13-24.

Darby, B.J. and Ritts, B.D., 2007. Mesozoic structural architecture of the Lang Shan, North-central China: intraplate contraction, extension, and synorogenic sedimentation. *J. Structural Geology*, **29**, 2006-2007.

Darby, B.J., Davis, G. A., and Zheng, Y., 2001. Structure evolution of the southwestern Daqingshan, Yinshan belt, inner Mongolia, China. In: *Paleozoic and Mesozoic tectonic evolution of Central and Asia: From Continental Assembly to Intracontinental Deformation*, (M.S. Hendrix and G.A. Davis, G. A. eds). pp. 199-214. Boulder, Colorado, Geological Society of America Memoir 194.

Davis, G. A., Qian, X., Zheng, Y., Yu, H., Wang, C., Mao, T. H., Gehrels, G. E., Muhammad, S. and Fryxell, J. E., 1996. Mesozoic deformation and plutonism in the Yunmeng Shan: A Chinese metamorphic core complex north of Beijing, China. In: *The Tectonic Evolution of*

Asia (A. Yin T.M. and Harrison, T. A., eds.), pp. 253-280. Cambridge University Press, Cambridge, UK.

Davis, G.A., Wang, C., Zheng, Y., Zhang, J., Zhang, C. and Gehrels, G.E., 1998. The enigmatic Yinshan fold-and-thrust belt of northern China: New views on its intraplate contractional styles. *Geology*, **26**, 43-46.

Davis, G. A., Zheng, Y., Wang, C., Darby, B.J., Zhang, Ch, and Gehrels, G. E., 2001. Mesozoic tectonic evolution of the Yanshan fold and thrust belt, with emphasis on Hebei and Liaoning provinces, northern China. In: *Paleozoic and Mesozoic tectonic evolution of Central and Asia: From Continental Assembly to Intracontinental Deformation* (M.S. Hendrix and G.A. Davis, eds.), Geological Society of American Memoir 194, 171-194.

Davis, G. A., Darby, B. J., Zheng, Y. and Spell, T. L., 2002. Geometric and temporal evolution of an extensional detachment fault, Hohhot metamorphic core complex, Inner Mongolia, China. *Geology*, **30**, 1003-1006.

Dong, SW., Zhang, Y., Long, C., Yang, Z., Ji, Q., Wang, T., hu, J. and Chen X. et al., 2008. Jurassic revolution and new interpretation of Yanshan Movement. *Acta Geologica Sinica*, **82**, 334-347.

Donskaya, T., Windley, B., Mazukabzov, A., Kröner, A., Sklyarov, E., Gladkochub, D., Ponomarchuck, V., Badarch, G., Reichow, M. and Hegner, E., 2008. Age and evolution of late Mesozoic metamorphic core complexes in southern Siberia and northern Mongolia. *J. Geol. Soc.*, **165**, 405-421.

English, J. M. and Johnston, S.T., 2004. The Laramide orogeny: What were the driving forces? *Int. Geol. Rev.*, **46**, 833-838, doi:10.2747/0020-6814.46.9.833.

Faure M., Trap, P., Lin W., Monié P. and Bruguier O., 2007. Polyorogenic evolution of the Paleoproterozoic Trans-North China Belt, new insights from the in Lüliangshan-Hengshan-Wutaishan and Fuping massifs. *Episodes*, **30**, 96-107.

HBGMR (Hebei Bureau of Geology and Mineral Resources), 1989. Regional geology of Hebei Province. Ministry of Geology and Mineral Resources, Geological Memoirs, ser. 1, **15**, 1741 pp. (in Chinese with English summary).

Hou, G., Wang, Y. and Hari, K. R., 2010. Late Jurassic stress fields and tectonic transmission of North China Craton. *J. Geodynamics*, **50**, 318-324.

He, Z., Li, J., Niu, B. and Ren, J., 1998. A Late Jurassic intense Thrusting-uplifting event in the Yanshan-Yinshan area, northern China, and its sedimentary response. *Geol. Review*, **44,** 407-418.

He, Z., Wang, Z. and Ren, J., 1999. A preliminary research on sedimentary features and genetic mechanisms of frontal basins before Jurassic large-scale nappe in the northern region of North China. *Sci. Geol. Sinica*, **34**, 186-195.

He, Z. and Niu, B., 2004. Re-inquiring of the "Chengde Thrust Plate": evidence from the Mesoproterozoic Changchenggian Sedimentary Facies in the Yanshan region. *Geol. Review*, **50**, 464-470.

Hu, J., Zhao, Y., Liu, W. and Xu, G., 2010. Early Mesozoic deformations of the eastern Yanshan thrust belt, northern China: *Int. J. Earth Sci*., **99**, 785-800, doi:10.1007/s00531-009-0417-5.

Huang, T.K., 1978. An outline of the tectonic characteristics of China. *Eclogae Geol. Helvetiae*, **71**, 611-635.

Kusky, T. M. and Li, J. H., 2003. Paleoproterozoic tectonic evolution of the North China Craton. *J. Asian Earth Sci*., **22**, 383-397.

Kusky T.M.,Windley, B., and Zhai, M., 2007, Tectonic evolution of the North China Block: from orogen to craton to orogen. In: *Mesozoic sub-continental lithospheric thinning under eastern Asia* (M. Zhai, B. Windley, T. Kusky, Q. Meng, eds). Geol. Soc., London, Special Publications **280**, 1-34.

Lin, W., Faure, M., Monié, P., Schärer, U. and Panis, D., 2008. Mesozoic extensional tectonics in Eastern Asia: The South Liaodong Peninsula Metamorphic Core Complex (NE China). *Journal of Geology*, **116**, 134-154.

Lin, W., Faure, M., Monié, P., and Wang, Q. C., 2007. Polyphase Mesozoic tectonics in the eastern part of the North China Blocks: insights from the Liaoning Peninsula massif (NE China). In: *Mesozoic sub-continental lithospheric thinning under eastern Asia* (M. Zhai, B. Windley, T. Kusky, Q. Meng, eds). Geol. Soc., London, Special Publications **280**, 153-170.

Lin, W. and Wang, Q., 2006. Late Mesozoic extensional tectonics in North China Block - Response to the Lithosphere removal of North China Craton. *Bull. de la Société Géologique de France,* **177**, 287-294.

Liu, J., Davis, G., Lin, Z. and Wu, F., 2005. The Liaonan metamorphic core complex, southeastern Liaoning Province, North China: A likely contributor to Cretaceous rotation of eastern Liaoning, Korea and contiguous areas. *Tectonophysics*, **407**, 65-80.

Liu, J., Zhao, Y. and Liu, XM., 2006. Age of the Tiaojishan formation volcanics in the Chengde basin, northern Hebei province. *Acta Petrologica Sinica*, **22**, 2617-2630.

Liu, Z., Xu, Z., Yang, Z., Liu, M., Zhao, D. and Zhao, Y., 2004. Discovery of Shihelagou thrust nappe and its geological sgnificance. *Geol. Survey and Research,* **27**, 24-27.

Liu, S. and Yang, S., 2000. Upper Triassic–Jurassic sequence stratigraphy and its structural controls in the western Ordos Basin, China. *Basin Res.,* **12**, 1-18.

Liu, S., Zhang, J., Hong, S. and Ritts, B., 2007. Early Mesozoic Basin Development and Its Response to Thrusting in the Yanshan Fold-and-Thrust Belt, China. *Int. Geol. Review*, **49**, 1025–1049

Luo, Z., Qiu, Y., Guan, K., Miao, L., Qiu, YM., Mc Naughton, N. J. and Groves, D.I., 2001. SHRIMP U-Pb dating on zircon from Yuerya and Niuxinshan granite intrusions in Eastern Hebei Province. *Bull. of Mineralogy*, **20**, 278-285.

Luo, Z., Miao, L., Guan, K., Qiu, Y., Qiu, YM., Mc Naughton, N.J. and Grooves, D.I., 2003. SHRIMP U/Pb dating of the Dushan granitic batholith and related granite-porphyry dyke, eastern Hebei Province, China, and their geological significance. *Geochimica*, **32**, 173-180.

Meng, Q., 2003. What drove late Mesozoic extension of the northern China-Mongolia tract? *Tectonophysics,* **369**, 155-174.

Mercier, J., Hou, M., Vergély, P. and Wang, Y. 2007. Structural and stratigraphical constraints on the kinematics history of the Southern Tan–Lu Fault Zone during the Mesozoic Anhui Province, China. *Tectonophysics*, *439*, 33-66.

Ritts, B.D., Darby, B.J. and Cope, T., 2001. Early Jurassic extensional basin formation in the Daqing Shan segment of the Yinshan belt, northern North China Block, Inner Mongolia. *Tectonophysics*, **339**, 239-258.

Teilhard de Chardin, P. and Licent, E., 1924. Observations géologiques sur la bordure occidentale et méridionale de l'Ordos: *Bull. de la Société Géologique de France*, **24**, 49-91.

Trap, P., Faure, M., Lin, W. and Monié, P., 2007. Late Palaeoproterozoic (1900–1800Ma) nappe stacking and polyphase deformation in the Hengshan-Wutaishan area: implication for the understanding of the Trans-North China Belt, North China Craton. *Precambrian Res.*, **156**, 85–106.

Trap, P., Faure, M., Lin, W., Le Breton, N. and Monié, P., in press. Paleoproterozoic tectonic evolution of the Trans-North China Orogen: Toward a comprehensive model. Precambrian Res.

Vergely, P., Hou, M., Wang, Y. and Mercier, J., 2007. The kinematics of the Tan-Lu Fault Zone during the Mesozoic-Palaeocene and its relations with the North China-South China Block collision (Anhui Province, China). *Bull. de la Société Géologique de France,* **178**, 353-365.

Wang, Y., 2006. The onset of the Tan-Lu fault movement in eastern China. *Terra Nova*, **18**, 423-431.

Wang, Y., Zhiu, L., Zhao, L., Ji, M. and Gao, H., 2010. Palaeozoic uplands and unconformity in the North China Block: constraints from zircon LA-ICP-MS dating and geochemical analysis of bauxite. *Terra Nova*, **22**, 264-273.

Wang, J., Faure, M., Chen, Y. and Lin, W., 2011. Polyphase deformation recorded from Mesozoic granitoids in the North China Block and its geodynamic significance. Example from the Yunmengshan granodiorite. 2011, EUG European Geosciences Union, Vienna, **13**, 1798.

Wong, W.H., 1927. Crustal movements and igneous activities in eastern China since Mesozoic times. *Geological Society of China Bull.*, **6**, 9-37.

Wong, W.H., 1929. The Mesozoic orogenic movement in eastern China. *Geological Society of China Bull.*, **8**, 33–44.

Yang, Z., Chen, Y., and Wang, H., 1986. *The Geology of China*. Clarendon Press, Oxford, 303 pp.

Zhang, X. and Song, H., 1998. The E-W trending strike-slip fault system in Xinlong, Hebei. *Regional Geology of China*, **16**, 180-187.

Zhang, C, Song, H., Wang, G., Yan, D. and Sun, W., 2001. Mesozoic dextral strike-slip structural system in Middle segment of intraplate Yanshan orogenic belt, Northern China. *Earth Science*, **26**, 464-472.

Zhang, Y., Liao, C., Shi, W., Zhang, T. and Gui, F., 2007. Jurassic deformation in and around the Ordos basin, North China. *Earth Science Frontiers*, **14**, 182-196.

Zhang Y., Dong S., Zhao Y. and Zhang T., 2008. Jurassic Tectonics of North China: a Synthetic View. *Acta Geologica Sinica*, **82**, 310-326.

Zhao, Y., 1990. The Mesozoic orogenic and tectonic evolution of the Yanshan Area. *Geol. Rev.*, **36**, 1–13 (in Chinese with English abstract).

Zhao, G., Sun, M. and Wilde, S., 2005. Late Archean to Paleoproterozoic evolution of the North China Craton: key issues revisited. *Precambrian Res.*, **136**, 177-200.

Zhao, Z., Yang, S., Chen, H., Zhu, G. and Zhou, J., 2000. Tectonic attribute of basement in Hefei Basin, Anhui Province, China. *Chin. J. Geol.*, **35**, 288–296

Zheng, Y., Wang, Y., Liu, R. and Shao, J., 1988. Sliding-thrusting tectonics caused by thermal uplift in the Yunmeng Mountains, Beijing, China. *J. Structural Geology*, **10**, 135-144.

Zheng, Y., Davis, G.A., Wang, C., Darby, B.J. and Hua, Y., 1998. Major thrust sheet in the Daquing Shan Mountains, Inner Mongolia, China. *Science in China*, **41**, 553-560.

Zhu, G., Wang, Y., Liu, G., Niu, M, Xie, C. and Li, C., 2005. $^{40}Ar/^{39}Ar$ dating of strike-slip motion on the Tan–Lu fault zone, East China. *J. Structural Geology*, **27**, 1379–1398.

Zhu, G., Liu, G., Niu, M., Xie, C., Wang, Y. and Xiang, B., 2009. Syn-collisional transform faulting of the Tan-Lu fault zone, East China. *Int. J. Earth Sci.*, **98**, 135-155.

Figure Captions

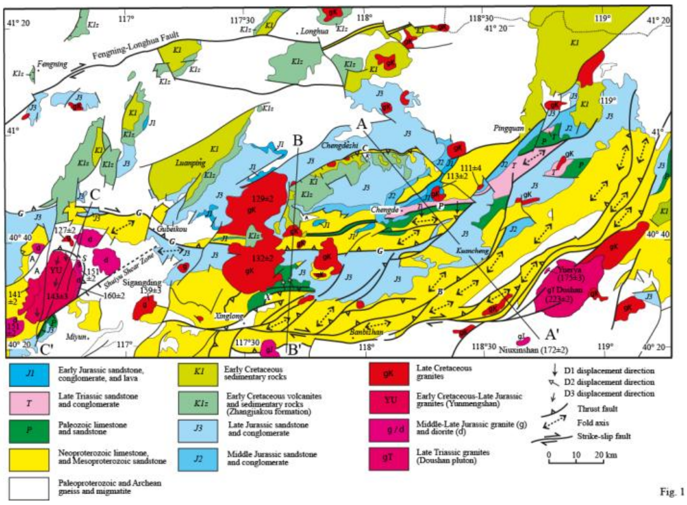


Figure 1. Structural map of the Yanshan belt, north of Beijing. C: Chengdeshi thrust, P: Pingquan-Gubeikou thrust, G: Gubeikou thrust, X: Xinglong thrust, B: Banbishan thrust, Shihetang thrust. YU: Yunmengshan pluton. Figures in plutons correspond to available zircon U-Pb ages.

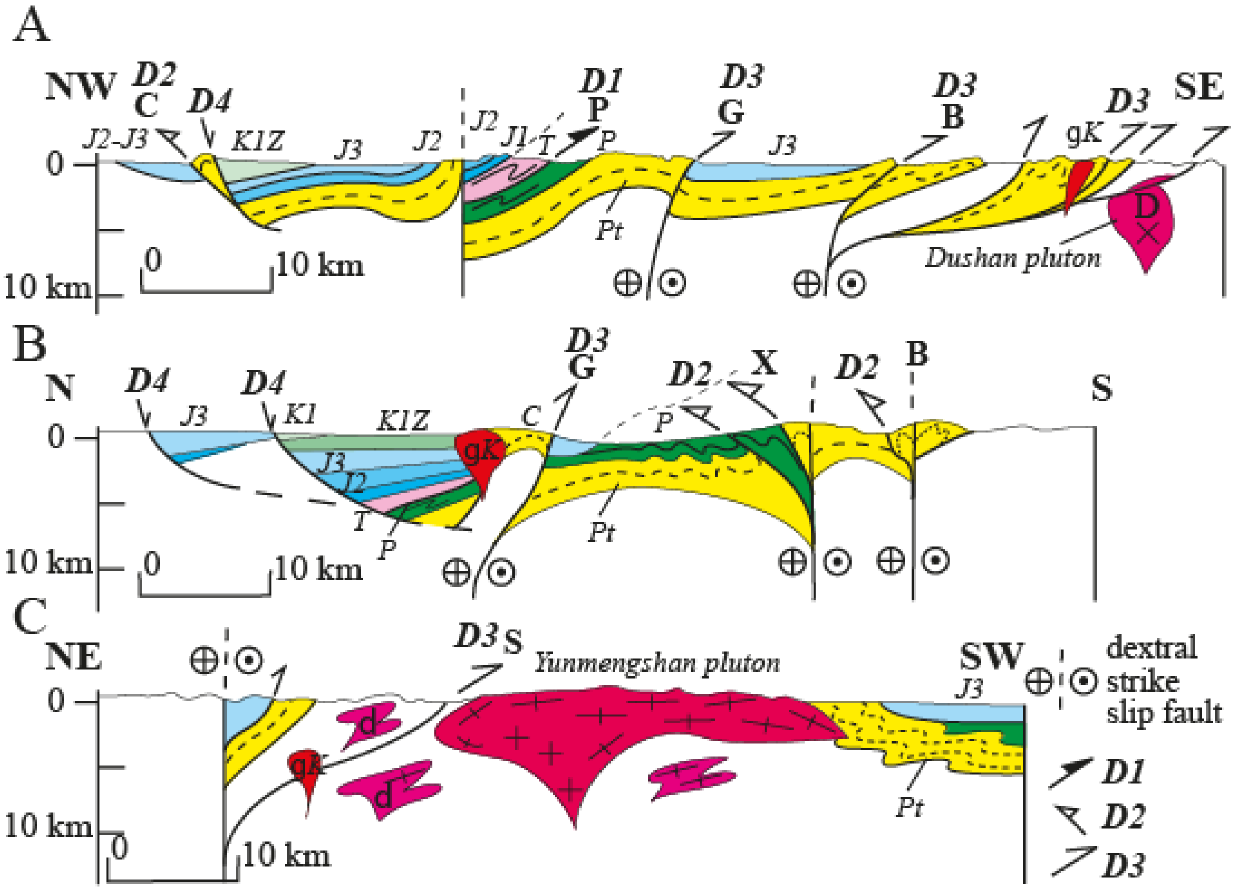


Fig. 2

Figure 2. Representative cross-sections through the Yanshan belt, (located in fig. 1), illustrating the structural style of the Mesozoic (Yanshanian) tectonics. D1, D2, D4, D4 refer to the deformation phases described in the text, see also Fig. 3 for the deformation age.

C: Chengdeshi thrust, P: Pingquan-Gubeikou thrust, G: Gubeikou thrust, X: Xinglong thrust, B: Banbishan thrust. YU: Yunmengshan pluton. Note the contrasted, northeastward and southeastward senses of motion along the thrust faults, and the lack of general polarity. Patterns and symbols are the same as for Fig. 1

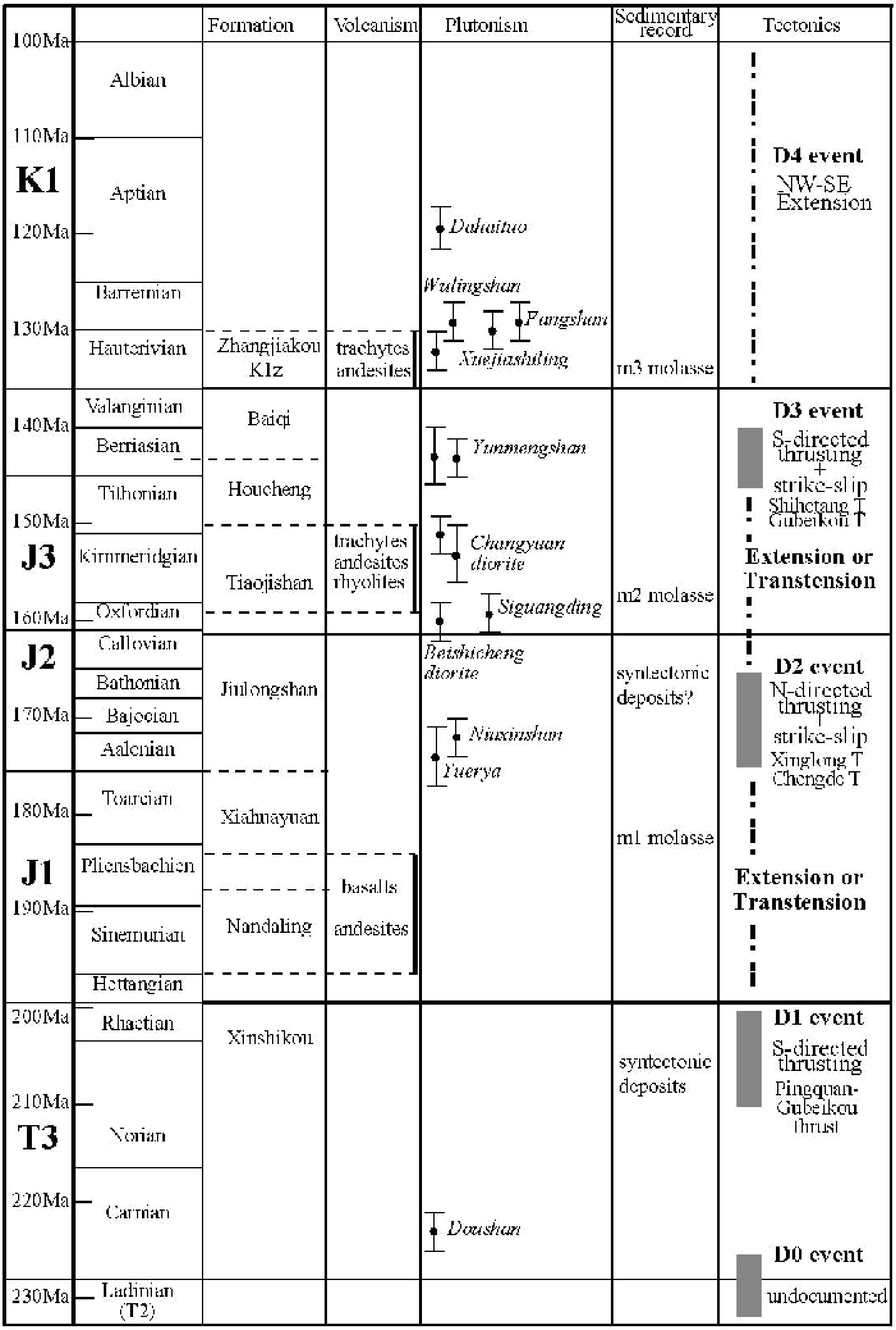


Fig. 3

Figure 3. Synoptic table of the Mesozoic volcanic, plutonic, sedimentary and tectonic events in the Yanshan area showing the timing of the five tectonic events, D_0 to D_4 described in the text.

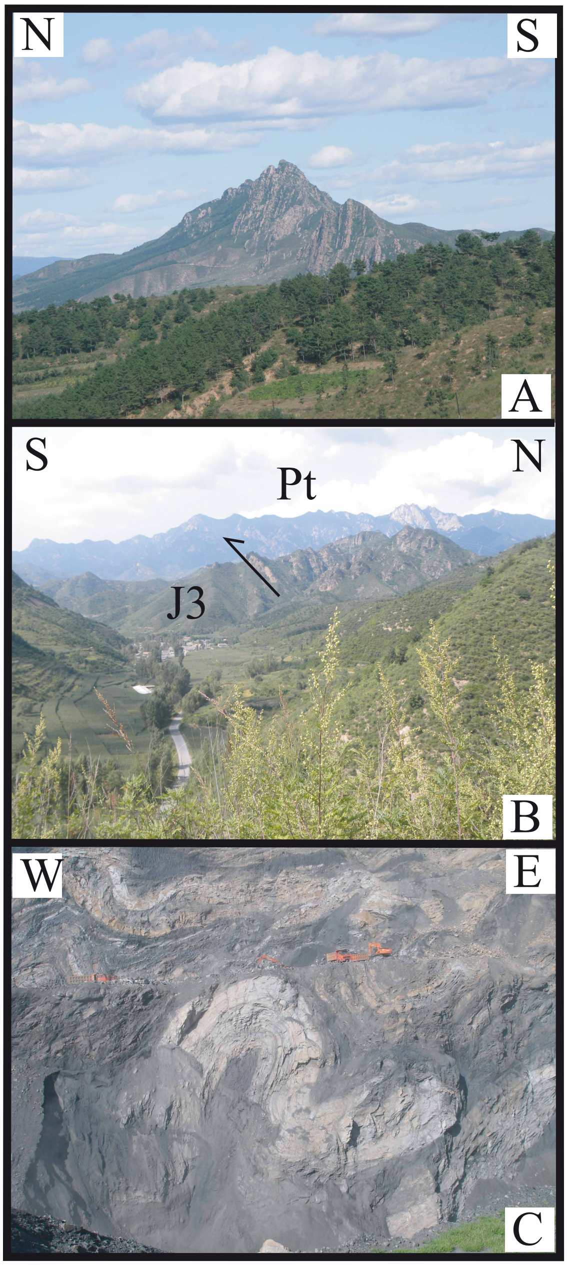

N
S
A
S
N
Pt
J3
B
W
E
C

Figure 4. Field pictures of the Jurassic deformation in the North China block.

A: Verticalized Proterozoic quartzite along the Fenging-Longhua dextral strike-slip fault;

B: Gubeikou thrust, S. of Chengde. Proterozoic sedimentary rocks (Changcheng group) (Pt) overthrust to the South Jurassic red beds (J3).

C: Plurimeter-scale East-verging folds in Late Paleozoic limestone-coal formation in the Helanshan (D_3 event North of Yinchuan).

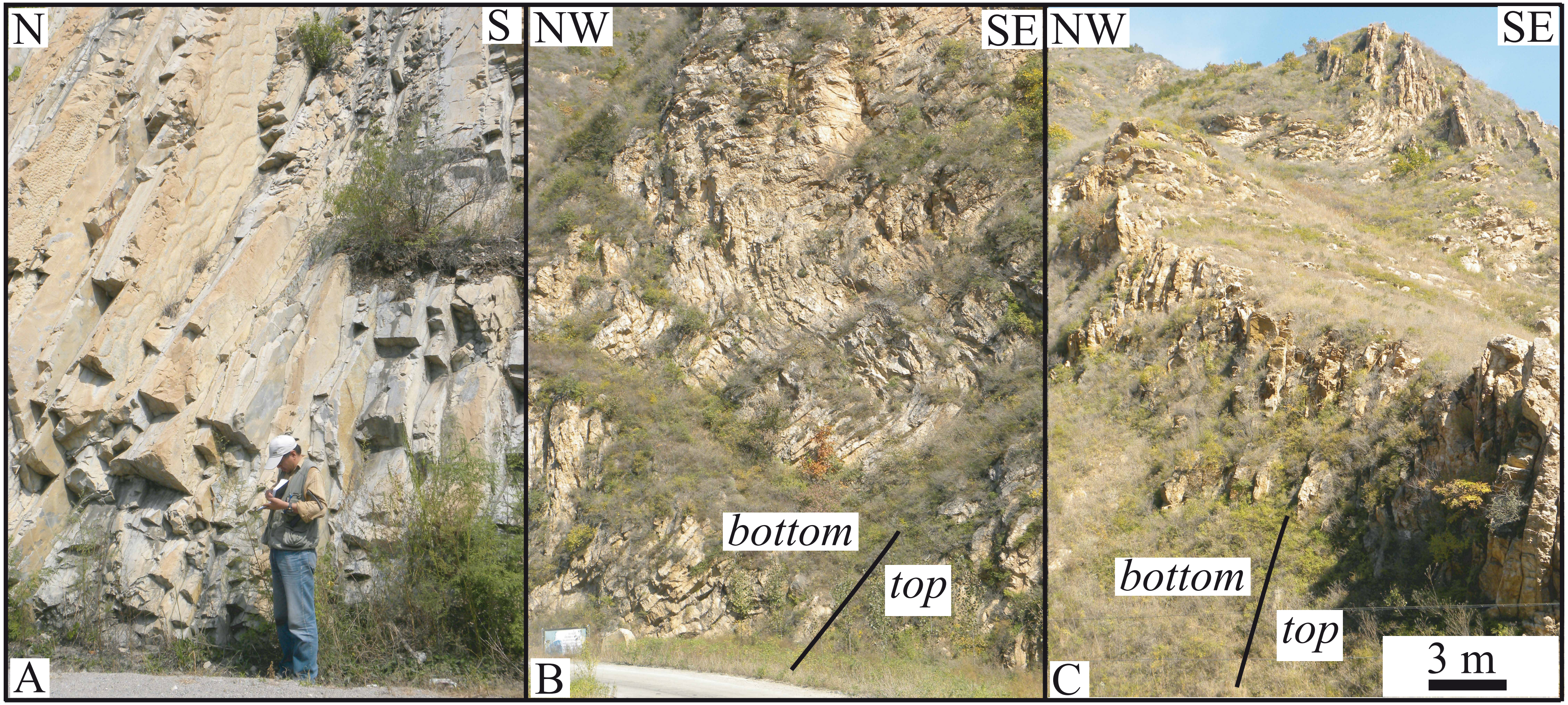

N
S
A
NW
SE
bottom
top
B
NW
SE
bottom
top
3 m
C

Figure 5. A: Load cast in verticalized but not ductilely deformed Proterozoic sandstone (Changcheng group, Northeast of Chengde).

B, C: South or Southeast overturned folds in Proterozoic sandstone (SE of Kuancheng), the beds are locally overturned.

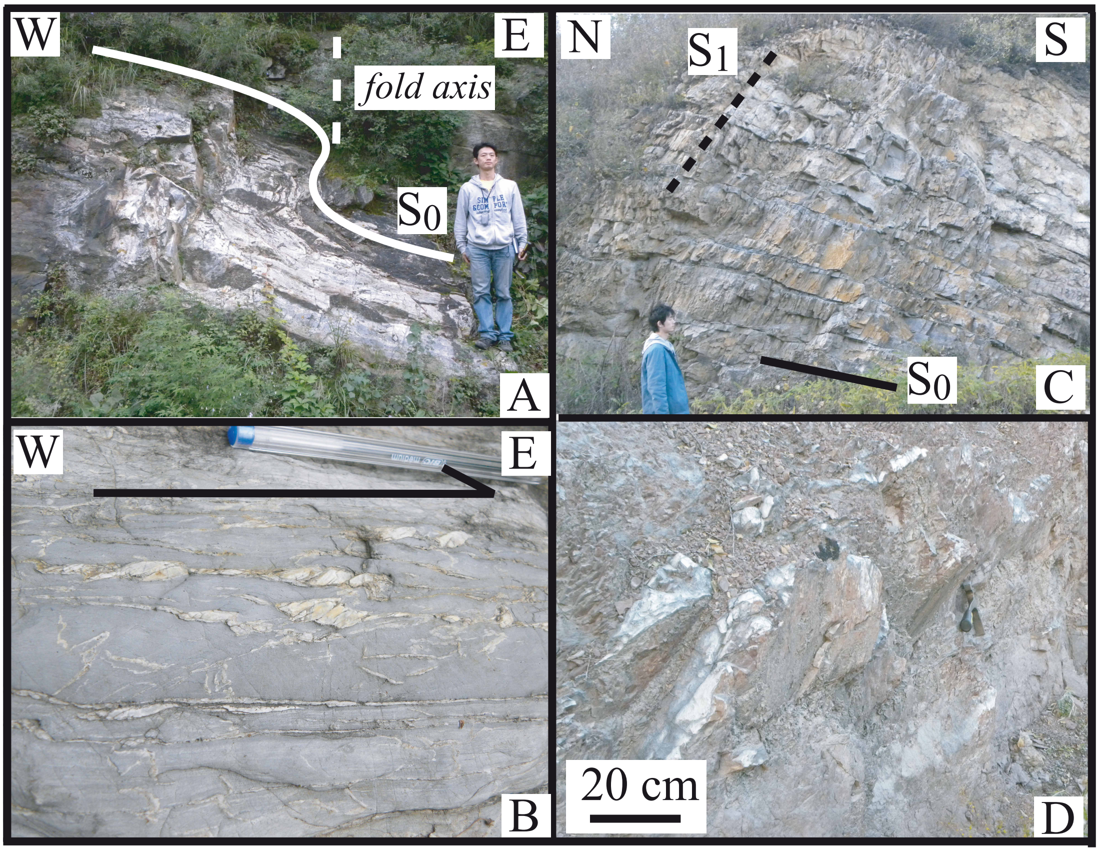

W
E
fold axis
S0
A
N
S
S1
S0
C
W
E
B
20 cm
D

Figure 6A: Asymmetric fold with vertical axis in Proterozoic limestone (Jixian group), indicating a dextral shearing (D_3 event, North of Yunmengshan pluton).

B: Asymmetric dolomite boudins in Proterozoic limestone indicating a dextral ductile shearing (D_3 event, North of Yunmengshan pluton).

C: South-verging fold with axial planar cleavage in Proterozoic sandstone (SE of Kuancheng).

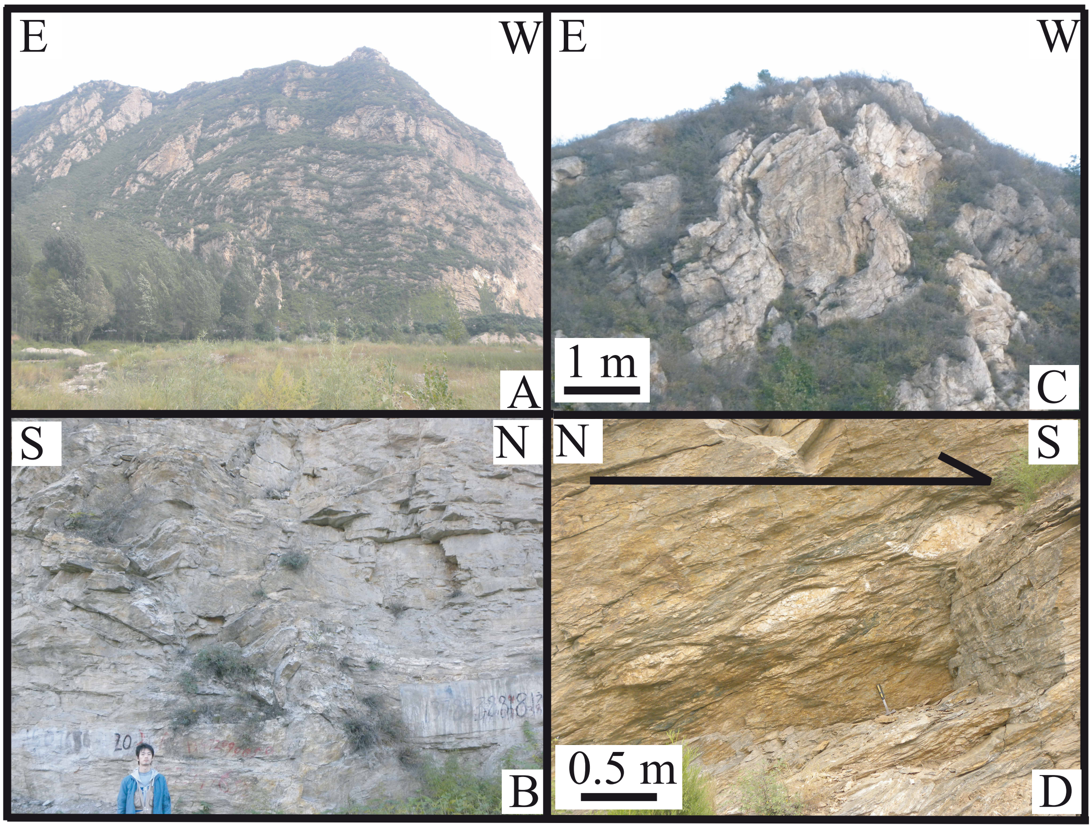
D: Schistose Triassic sandstone and siltstone along the Pingquan-Gubeikoi thrust (East of Chengde).

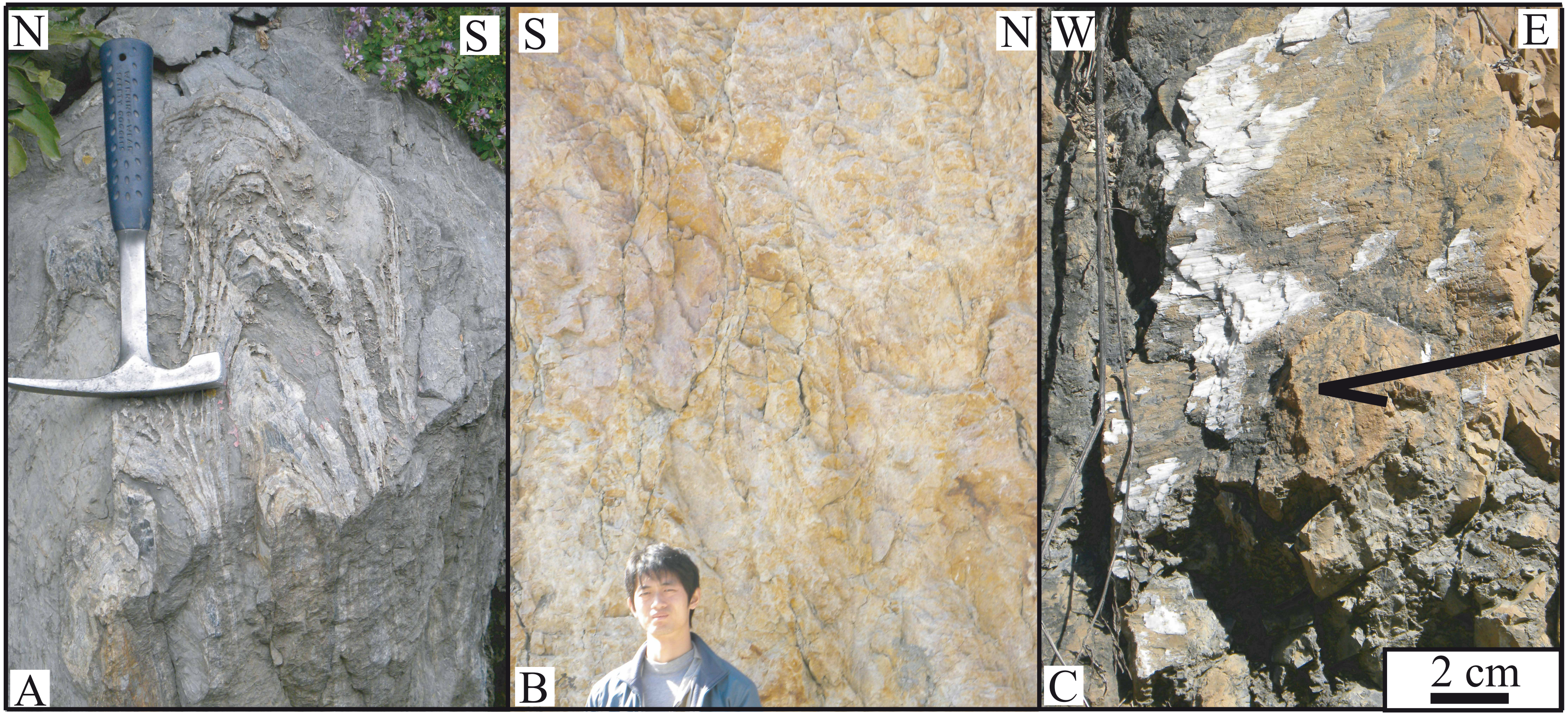
Figure 7A: Southeastward-verging fold in Proterozoic sandstone (East of Banbishan).

B: South-directed high-angle thrust in Proterozoic sandstone (SE of Kuancheng).

C: East-verging fold in Proterozoic sandstone (North of Dushan pluton).

D: Top-to-the-South asymmetric granite boudins in the Proterozoic country rocks of the Yunmengshan pluton, close to the Shihetang thrust.


E
W
A
E
W
1 m
C
S
N
B
N
S
0.5 m
D



N
S
A
S
N
B
W
E
C
2 cm

Figure 8A: Fold with vertical axis in Proterozoic limestone(Jixian group) associated with strike-slip faulting along the Gubeikou thrust (North of Yunmengshan pluton).

B: Vertical section perpendicular to the D_3 dextral strike-slip fault, east of Banbishan showing sigmoidal lenses developed in Neoproterozoic (Changcheng) sandstone.

C: Horizontal slickenlines and calcite steps indicating a dextral strike-slip motion along the Banbishan “thrust” (East of Banbisahan).

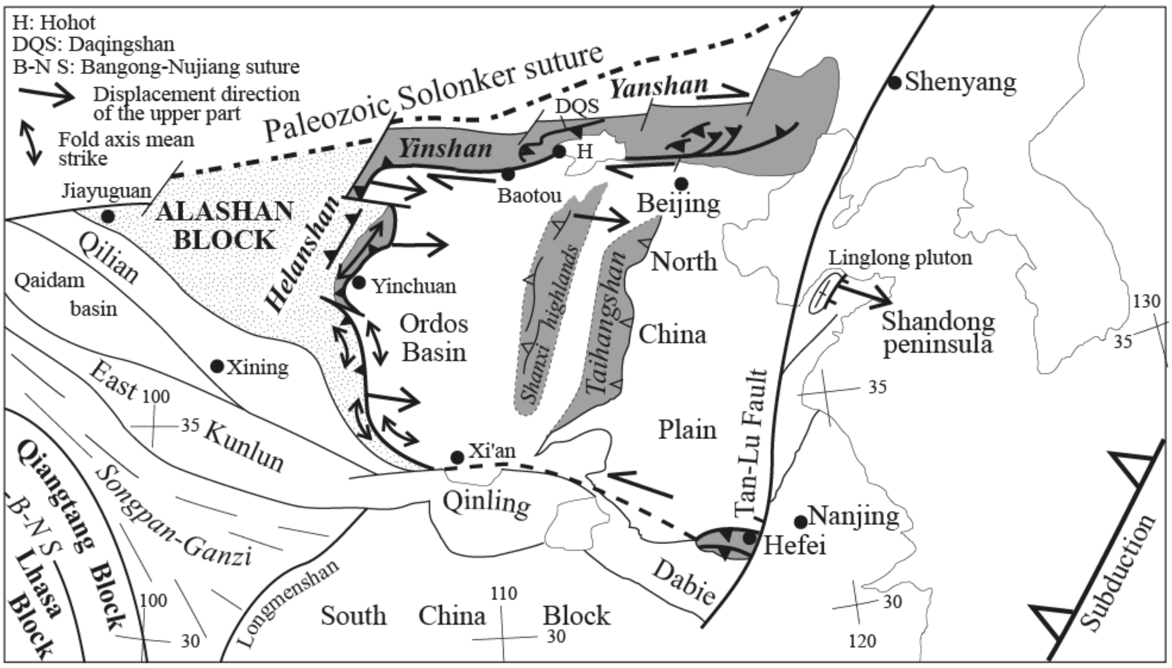


Figure 9: Interpretative structural map of the Jurassic tectonics of the North China Block (NCB). Grey pattern highlights fold-and-thrust belts. The E-W Yanshan-Yinshan belt developed as a dextral strike-slip along which North and South directed thrusts represent positive flower structures. This belt connects to the SW with the Helanshan belt characterized by East-directed folds and thrusts. To the South, left-lateral strike-slip develops along the northern margin of the Qinling-Dabie belt. To the East, sinistral wrenching and NW-SE normal faulting are recognized along the Tan-Lu fault and in the Shandong peninsula. Between the Ordos basin and the North China plain, the Shanxi highlands and the Taihangshan are east-directed fold-and thrust belts formed by thin-skin tectonics. As a whole, the NCB understhrusts to the West below the Alashan Block.

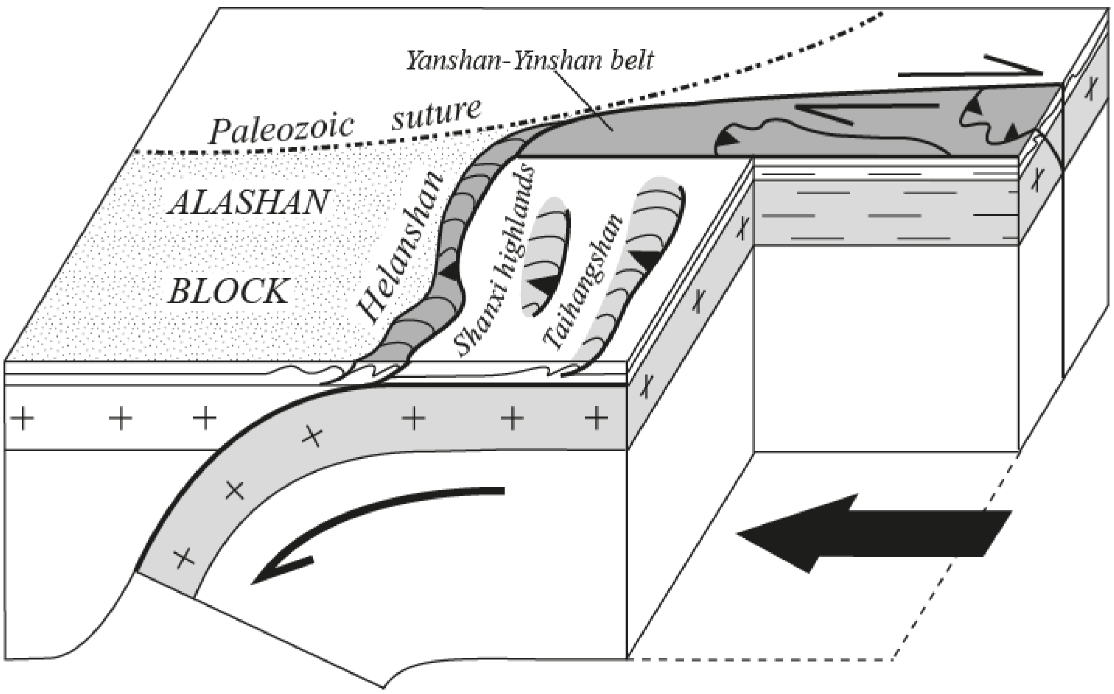


Figure 10: Schematic block-diagram showing the continental subduction of the North China Block below the Alashan block. The main decollement is located in the Helanshan area. Subordinate fold-and-thrust belts develop in the Shanxi highlands and Taihangshan. The intracontinental Yanshan-Yinshan belt is interpreted as a transpressional orogen formed along an East-West striking strike-slip system.