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Structural evolution of metamorphic rocks in the Talas Alatau, Tien Shan, Central Asia: Implication for early stages of the Talas-Ferghana Fault

Évolution structurale des roches métamorphiques du Talas Alatau, Tien Shan, Asie centrale : implication pour les stades précoces de la Faille du Talas-Ferghana

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ABSTRACT

The Talas Alatau Ridge consists of three tectonic units separated by thrusts. The central (Talas parautochthon) and northeastern (Kumyshtag sheet) parts consist mainly of unmetamorphosed terrigenous and carbonate deposits. The southwestern part of the Talas Alatau (Usunakhmat sheet) consists of greenschists and is bounded by the Central Talas Thrust (CTT) and Talas-Ferghana Fault (TFF). The latter is a major strike-slip fault with post-Permian dextral displacement estimated at as much as 200 km. A structural study shows that elongation axes of strain ellipsoids, stretching lineation and map-scale fold axes, as well as the trend of major faults including the CTT and the TFF, are parallel to each other. The natural deviatoric strain value gradually increases from the CTT to the TFF. The shape of the strain ellipsoid gradually varies within the Usunakhmat sheet from oblate at the frontal thrust to prolate in internal parts of the unit. The magnitude of shortening increases towards the CTT, whereas natural deviatoric strain decreases towards the CTT implying structural thickening of internal parts of the Usunakhmat sheet. Strong parallelism of the TFF, CTF and other map- and outcrop-scale structures and their close connection with strain patterns show that they were formed during the same tectonic event. They were likely formed during Middle to Late Ordovician collision and built up Kyrgyzian microcontinent as a thrust fold belt whereas reactivation of the TFF as a strike-slip fault occurred later, in Late Paleozoic.

Mots clés :
Paléozoïque inférieur
Analyse de contrainte
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Déformation
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Asie centrale

RÉSUMÉ

La Chaîne de Talas Alatau consiste en trois unités tectoniques séparées par des charriages. Les parties centrale (parautochtone de Talas) et nord-orientale (unité de Kumyshtag) sont constituées essentiellement de dépôts carbonatés et terrigènes non métamorphosés. La partie sud-occidentale du Talas Alatau (unité d'Usunakhmat) consiste en schistes verts et est limitée par le charriage central de Talas (CTT) et par la Faille de Talas-Ferghana (TFF). Cette dernière est un décrochement majeur, avec déplacement dextre post-Permien, estimé à environ 200 km. L'étude structurale montre que les axes d'élongation des ellipsoïdes de contrainte et les axes de plis à l'échelle de la carte, ainsi que la déformation des failles majeures incluant CTT et TFF sont parallèles les uns par rapport aux autres. La valeur naturelle de la contrainte de déviatorique augmente graduellement de CTT à TFF. La

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forme de l'ellipsoïde de contrainte varie aussi graduellement, au sein de l'unité d'Usunakhmat, d'oblate au front du charriage à prolate dans les parties internes de l'unité. L'amplitude du raccourcissement augmente vers CTT, tandis que la contrainte déviatorique naturelle décroît vers CTT impliquant un épaississement structural des parties internes de l'unité d'Usunakhmat. Un parallélisme intense de TFF, CTF et d'autres structures à l'échelle de la carte ou de l'affleurement et leur connexion étroite avec les configurations de contrainte montrent que TFF et CTF se sont formés pendant le même évènement tectonique : leur genèse a vraisemblablement pris place lors de la collision à l'Ordovicien moyen-supérieur et donné naissance au microcontinent Kyrgyzian en tant que ceinture plisée de charriage, alors que la réactivation de TFF en tant que faille de décrochement s'est produite plus tard, au Paléozoïque supérieur.

1. Introduction

The Talas-Ferghana Fault (TFF) is located in the western part of the Tien Shan mountains (Central Asia) and is one of the world's largest strike-slip faults located on the continental crust with dextral displacement up to 200 km (Burtman, 1975, 1980, 2006; Burtman et al., 1996). Its northwest continuation is the Main Karatau Fault (MKF), whereas southeastward it cuts Caledonian and Hercynian structures of the Middle and southern Tien Shan (Fig. 1a). The age of the TFF and the MKF is not clear, but, according to data on the displacement of Paleozoic and younger rocks, it is commonly assumed that the dextral displacement started in the Permian. However, Khudoley and Semiletkin (1992a) interpreted the TFF, Central Talas Thrust (CTT) and northeast-vergent thrusts as a single imbricate thrust fan, formed in the Early Paleozoic with the Late Paleozoic reactivation of the TFF as a strike-slip fault.

Starting from Karatau in the north, up to the Naryn part of the Middle Tien Shan in the south, metamorphic rocks of greenschist to amphibolite grade are distributed mainly in the northeastern side of the MKF and TFF faults. The age of metamorphic rocks was traditionally assumed as Neoproterozoic (Abad et al., 2003; Bakirov and Dobretzov, 1972; Becker et al., 1988; Chakabaev, 1979; Kiselev and Korolev, 1981; Sagyndykov, 1964). However, sedimentary units correlation based on the detailed structural and sedimentological studies as well as rare findings of fauna fossils give evidence for a Paleozoic age of the metamorphic rocks (Khudoley and Semiletkin, 1992a; Kiselev and Maksumova, 2001; Maksumova et al., 2001).

Although structural studies in the study area and adjacent regions were done by many researchers (Abad et al., 2003; Alexeiev et al., 2009; Becker, 1987; Burtman, 1975; Burtman et al., 1996; Frolova, 1982; Goncharov, 1998; Khudoley and Semiletkin, 1992a; Yakovlev, 1976), strain patterns were discussed only in a few papers (Khudoley, 1993; Pastor-Galán et al., 2009; Voitenko et al., 2006). The main goal of this article is to discuss structures and strain patterns of the metamorphic rocks located in the central part of Talas Alatau Ridge with emphasis on the strain analysis and relationship between the TFF and other structures of the metamorphic rocks that will help to understand the early evolution of the TFF.

2. Geological background

2.1. Regional setting

The Talas Alatau Ridge is located in the northwestern part of the Republic of Kyrgyzstan. The main tectonic and stratigraphic features of the region are shown in Figs. 1 and 2.

Most of the Talas Alatau Ridge belongs to the southeastern part of the Caledonian Talas-Karatau zone of the northern Tien Shan (Fig. 1b). Its southwest boundary is the TFF, which separates it from the Hercynian Middle Tien Shan, whereas the Ichkeletau-Susamyr Fault separates it from the northern Tien Shan Caledonides (Kokchetav-northern Tien Shan microcontinent) in the northeast (Fig. 1c) (Maksumova et al., 2001).

The Caledonian part of the Talas Alatau Ridge discussed in this article consists of three tectonic units (Khudoley, 1993; Khudoley and Semiletkin, 1992a). The lowermost unit is exposed in its central part and is interpreted as parautochthon or autochthon (Talas parautochthon, Figs. 1c and d). It consists of a coarsening-upward terrigenous succession deposited in submarine fan to shelf environments with some carbonate units in its central part (Fig. 2). The total thickness of the succession is estimated as 5 to 6 km. The age of the succession was traditionally accepted as Neoproterozoic (Abad et al., 2003; Becker et al., 1988; Kiselev and Korolev, 1981). However, findings of rare fauna fossils show that at least the upper part of the succession is as young as Cambrian to Middle Ordovician in age (Fig. 2) (Khudoley and Semiletkin, 1992a; Kiselev and Maksumova, 2001; Maksumova et al., 2001; Semiletkin, 2007 and references therein). It resulted in a significant revision of ideas on the structure and evolution of the Talas parautochthon. Metamorphic alteration of rocks is low and gradually increases southwestward (Abad et al., 2003; Frolova, 1982). Thus, in the northeastern exposures of terrigenous rocks, cleavage was only documented in slate, whereas in the southwestern exposures cleavage is widespread in both slate and sandstones. More intense metamorphism up to biotite sub-grade was only documented around the Babakhan plagiogranite intrusion.

The Kumyshtag sheet consists of Latest Neoproterozoic non-marine and shallow marine siliciclastics with subordinate acid tuffs and Cambrian to Middle Ordovician