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Sand Body Provenance Analysis of Taiyuan Formation in Datong Coal Basin

Xiaoli Cui*

Department of Civil Engineering, Sichuan staff University of Science and Technology

*Corresponding author e-mail: cxlzx@126.com

Abstract: Coal provenance analysis is an important part of coal research, of referential significance for coal-seeking direction determination, coal-rock formation comparison, coal enrichment zone location prediction, exploration of coal seam thickness variation laws, and estimation of coal reserves/resources.

1. Introduction

Datong Coalfield is dominated by Carboniferous-Permian coal and Jurassic coal, witnessing double periods. Jurassic coal resources have gradually become exhausted. Carboniferous-Permian coal is the successor of Jurassic coal, and Taiyuan Formation is the main coal-bearing strata of Carboniferous-Permian coal^[1]. This paper analyzes the sedimentary resources of Taiyuan Formation in Datong Coal Basin and sedimentary evolution of the coal basin, expecting certain guidance for coal geological exploration and coal production.

2. Coal strata

Datong Coal Basin witnesses the north-east and south-west elliptical shape, with the principal structure experiencing the asymmetrical syncline, southeast wing experiencing the steep dip angle and northwest wing experiencing the gentle style.

Coal strata focus on: Paleozoic Carboniferous Taiyuan Formation, Paleozoic Permian Shanxi Formation, and Mesozoic Jurassic Datong Formation, with Taiyuan Formation as the main coal-bearing stratum and the research focus.

Taiyuan Formation is generally 80m-100m thick, gradually decreasing from south to north. Coal seam is 0.06m-47.45m thick, generally 17m. This formation has its lower part as ash-grey medium-grained sandstone (K₂), bordering underlying Benxi Formation (integrated contact), sandstone and mudstone inter-bed upward, #9 and #10 thin coal seams sandwiched, #8 coal seam (2m-6m thick) upward, marl and mudstone coal seams at the top.

This formation has its central part dominated by grey-white medium and coarse sandstone and gravel-bearing coarse sandstone, #6 and #7 coal seams sandwiched (locally recoverable), witnessing obvious rhythms and developed large-scale slab-like staggered bedding, unstable sandstone layers unstable, lateral grey-white sandy mudstone and siltstone, thick #5 coal seam (recoverable) further upward.

This formation has its upper part dominated by thick glutenite, pebbly coarse sandstone and medium coarse sandstone, inter-bedded with sandy mudstone and mudstone, with sandstone witnessing large interlaced and horizontal bedding, obvious rhythms, flushing surfaces at the bottom, and #4, #3 and #2 coal seams sandwiched.



3. Analysis of sand body provenance of Taiyuan Formation

The provenance area refers to the source area or maternal area of detrital materials in the basin. Provenance analysis infers petrological characteristics of the detrital provenance area based on final products of sedimentation and structure background and climatic conditions upon sedimentation. Provenance analysis can reflect the sediment provenance area location and nature, transport paths and various factors affecting the composition of sedimentary rocks^[2] (topographic relief, climate and tectonic setting). The skeleton mineral composition of sandstone was derived from weathering and denudation products of maternal rocks. Type, content, combination and optical characteristics of skeleton particles of sandstone can reflect the tectonic setting and nature of source rocks of the basic provenance area, witnessing correlation between sandstone components and source rocks of the provenance area. It is proper to judge structural properties of the provenance area according to the composition of the sandstone, and then study the basin sedimentary evolution. According to the sand body lithology characteristics of Taiyuan Formation, this paper analyzes the provenance with the detrital rock analysis method, determining the location of the provenance area in combination with paleocurrent direction, properties and tectonic setting of source rocks in the provenance area with the detrital component analysis method.

3.1 Component analysis of clastic particles

Detrital component recorded sedimentary evolution then, with obvious provenance indication. As the product of the weathering-sedimentary cycle of the provenance rock in the provenance zone, it reflected rock characteristics of the provenance area, and the sedimentary environment and transformation^[2]. Analysis of source rocks and material sources through sandstone detrital analysis is important to provenance analysis. Stratigraphic section measurement has found Taiyuan Formation has 7 layers - 10 layers of developed sand and conglomerate. This paper conducts microscopic identifications of sandstone samples, analysis and study based on medium and coarse sandstone clastic particle mineral composition, extinction characteristics and types, surface morphological characteristics, edge characteristics and crystal twin types, concluding rocks centering on quartz sandstone, detrital quartz sandstone, feldspar quartz sandstone, and feldspar lithic sandstone

Table 1 Statistics of Factors of Sandstone Detrital Components of Taiyuan Formation %

Stratum	Magmatic rock skeleton particle			Sedimentary rock skeleton particle		Metamorphic rock skeleton particle		
	Quartz (single crystal, polycrystalline)	Feldspar	Rock clastics	Quartz (single crystal, polycrystalline)	Rock clastics	Quartz (single crystal, polycrystalline)	Feldspar	Rock clastics
Taiyuan Formation	4.12	2.5		72.02	10.44	6.55		4.37

Microscopic observations found Taiyuan Formation had sandstone detrital component account for 14.81%, feldspar account for 2.5%, quartz account for 82.69%, and cement as siliceous and muddy. Quartz crumb particles consisted of polycrystalline quartz and single crystal quartz. Polycrystalline quartz was mostly polycrystalline aggregate composed of quartz particles with secondary enlarged edges, which should be sedimentary rock polycrystalline quartz. Secondly, the polycrystalline crystal composed of several quartz grains with different particle sizes in contact with suture. Such quartz should be of the metamorphic rock type. There was a small amount of polycrystalline quartz with flat contact lines, of the granite type. Microscopic single crystal quartz was mostly quartz particles with incomplete secondary enlarged edges, of the sedimentary rock types. In addition, single crystal quartz with black pitting and irregular cracks and extinction should be metamorphic rocks. And very few single crystal quartz with the condensed structure edge and bay-like uniform extinction, of the granite type.

Microscopic observations found Taiyuan Formation had flint rock debris composed of silty mudstone rock debris and microcrystalline quartz, as the sedimentary rock debris. Statistics indicated Taiyuan Formation had magmatic rock particles account for 6.62%, sedimentary rock particles account for 82.46%, degenerative rock particles account for 10.92%, indicating that the provenance area of Taiyuan Formation was dominated by sedimentary rocks upon sedimentation, but with increased erosion made terrestrial source magmatic rocks and metamorphic rocks gradually exposed to the surface.

3.2 Paleocurrent analysis

Paleocurrent analysis is an important reference for the provenance direction analysis. Through the study of various sedimentary structures of the outcrop profiles in the field, the direction of the paleocurrent could be analyzed^[3]. Many sedimentary structures of sedimentary rocks could be used as markers of paleocurrent. The tendency of the inter-bedded fine layers in the sandstone layer could indicate the direction of the paleocurrent (provenance area). This study centered on K₂ sandstone and the #5 coal seam sandstone of the bottom of Taiyuan Formation and outcrop in the field. Occurrence of rock formation and inter-bedded fine layers were systematically measured, and rock strata were restored with the polar projection method and the original appearance of the interlaced layer was applied, including 37 groups of K₂ sandstone interlaced fine layers, with the average trend after statistical correction as 149°, measuring #5 coal seam floor sandstone interlaced fine layer 49 groups, with the average trend as 154°. The analysis results indicated that the paleocurrent witnessing northwest to southeast upon Taiyuan Formation was deposited. The provenance area of the basin was Yinshan uplift on the north side of the basin.

3.3 Ancient structural features of the provenance area

Paleogeographic and paleo-tectonic background characteristics of the provenance area were closely related to type and content of sandstone clastic components in the sedimentary basins^[4]. Classification statistics of rock debris, quartz and feldspar in detrital components of Taiyuan Formation sandstone (Table 2)

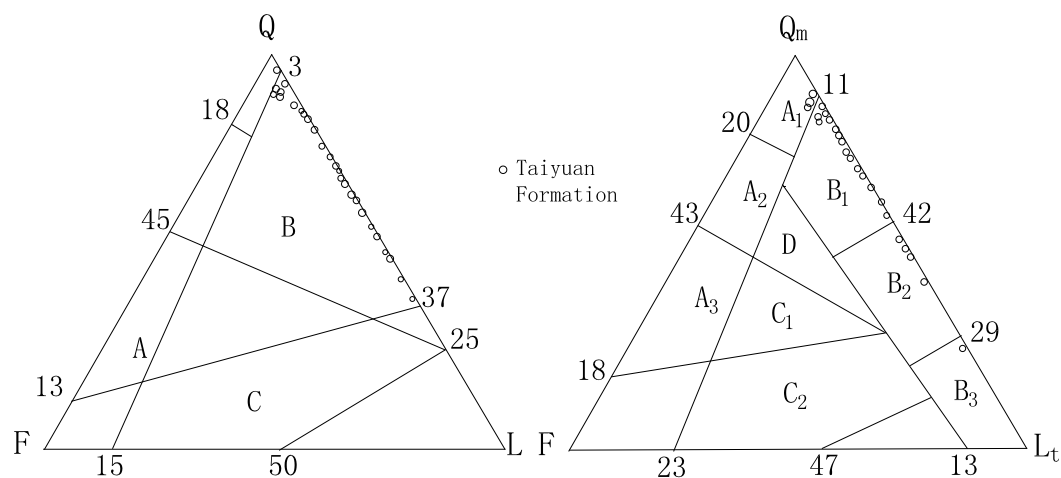
Table 2 Dickinson Parameter Table of Taiyuan Formation Sandstone Detrital Component

Stratum	Thickness /m	Q-F-L		
		Q	F	L
Taiyuan Formation	2.15	92	0	8
	2.87	95	0	5
	7.95	84	0	6
	2.46	89	0	11
	2.92	86	0	14
	2.68	90	0	10
	3.94	92	3	5
	2.06	95	0	5

Note: Q=Q_m+Q_p; Q=all quartz particles; Q_m=single crystal quartz; Q_p= polycrystalline quartz + vermiculite; F=all single crystal feldspar particles; L= rock debris;

The total amount of quartz and vermiculite of Taiyuan Formation was between 84% and 95%, with an average of 90.75%. The rock debris content was between 5% and 11%, with an average of 8.0%, and the feldspar content was up to 3%.

Statistics of the skeleton particles of Taiyuan Formation sandstone put into Q-F-L and Q_m-F-Lt diagrams of Dickinson et al (1983) (Fig. 1). Fig. 1 indicated in the Q-F-L diagram, Taiyuan Formation had its 54 samplers have 5.4% in the continental plate area, and 94.6% in re-spinning to the orogenic zone. Q_m-F-Lt diagram had 17.3% parameter points in Craton, 59.7% parameter points in the quartz re-spinning zone, and 23% parameter points in the transition re-spinning zone of quartz and rock debris;



A-continental plate; A1-craton intracontinental; A2-transitional continental; A3-basal uplift; B- re-spinning orogenic zone; B1-quartz re-spinning; B2-transitional re-spinning; B3-rock chip re-spinning; C-magmatic island arc; C1-cut island arc; C2-transition island arc; C3-uncut island arc; D-mixed zone; Q-quartz and siliceous rock debris; F-feldspar; L-all unsteady rock debris; Q_m-single crystal quartz; L_t-rock debris (including polycrystalline and microcrystalline quartz rock debris)

Fig.1 Diagram of Q-F-L and Q_m-F-L_t of Taiyuan Formation sandstone (according to Dickinson et al)

The graphical analysis of Q-F-L and Q_m-F-L_t diagrams of Taiyuan Formation sandstone skeleton particle components and regional geological development indicated terrigenous erosion zone was once a part of North China block during Taiyuan Formation sandstone deposition. Land-land collision between North China Plate and Siberian Plate made Yinshan area in the rear part of North China Plate uplifted, Datong Area subsided and witnessed depression in the Middle Carboniferous^[1], increasing in the Late Carboniferous and early Permian, increasing collision of the two major plates, and increasing land-provenance ablation zone, accompanied by fold-tectonic tectonics, resulting in exposure of ancient metamorphic rocks and previously invaded magmatic rocks to the surface, eroded, transported, and deposited.

4. Conclusion

Analysis of the location and physical characteristics of the provenance area during deposition of Taiyuan Formation in the Datong coal basin suggested the provenance area should be Yinshan uplift structural zone, but Yinshan structural zone should not be the long-term uplifting structural unit since Proterozoic Eonothem, instead, the early Carboniferous end together with collision of North China plate and Siberian plate, Yinshan structural zone gradually rose and became the provenance area of Datong Coal Basin.

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