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Characteristics of Coal Accumulation of Transform-Extensional Basins in Linear Fracture Zones: A Case Study of the Meihekou Basin

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Abstract This paper discusses the characteristics of coal accumulation of transfor-extensional basins in linear fracture zones on the basis of an analysis of tectonic evolution and sequence stratigraphy in the Meihekou basin. Coal accumulation of the basin occurred mainly in the accelerated rifting period of the transtentional regime and in the late period of tectonic transformation of the transpressional regime. In the former period, swamps developed in shallow lakes. The thickness of coal seams was controlled by the activity of fault block. Thick coal was formed in a downfaulted trough. In the latter period, swamps developed in a braided fan delta plain. The coal seams are thin and have poor lateral continuity. The thickness of coal seams was controlled by the migration of water channels in the braided plain.

Key words: coal accumulation, sequence stratigraphy, tectonic evolution, Meihekou basin

1 Tectonic Evolution of the Basin

The Meihekou Basin is located in the Fushun-Mishan fault zone, a branch of the northern part of the Tancheng-Lujiang fault zone. The Fushun-Mishan fault zone is an important Tertiary coal accumulation zone in eastern China. A series of coal-accumulating basins were developed along this fault zone, among which the Meihekou basin is a relatively big one (Fig. 1). Because of its intense late-stage deformation, the original sedimentary borders of the northwest margin were eroded and show a fault contact with the Cretaceous purplish-red conglomerate. There are residual marginal-facies deposits only in some local regions outside the basin. The southeastern margin of the basin with think conglomerate wedges approaches the original depositional margin. The basin covers an area of about 150 km^2 (c. 5 km in the NW-SE direction and c. 26 km in the NE-SW direction).

The Fushun-Mishan fault is an important active one in eastern China since the Cenozoic (Du Dongju, 1985). The Tertiary basins along this fault zone were the results of Palaeogene rifting, one of the important rifting stages in eastern China. They were closely related to the evolution of the Bohai Bay basin in eastern China, and were under the same palaeotectonic stress field. The evolution of the basin was controlled by both extension and strike-slipping (Li Sitian et al., 1997).

The tectonic evolution of the basin can be divided into two episodes. The filling strata during the second episode were seriously eroded and the first episode can be subdivided into the rifting stage and the inversion stage. During the rifting stage, the basin was subjected to block faulting controlled by the regional dextral transtensional regime, forming a series of high-angle syndepositional normal faults (Figs. 2 and 3). There are two sets of syndepositional faults in the basin: the dominant NE-SW set (parallel to the direction of the basin) and the subordinate NNE-SSW set. The main faults lie on the southeast side of the basin, forming a half-graben tectonic pattern with faults on the northwest side and onlap on the southeast side. Inversion of the basin was controlled by the sinistral transpression tectonic regime, which resulted in the inversion of some syndepositional faults and transformation of some fault depressions into fault uplifts (Fig. 4).

After the Meihekou basin was formed, it underwent a relatively intense sinistral transpression deformation. From Fig. 5, it can be seen that a series of thrust faults and strike-slip faults were developed on the northwest

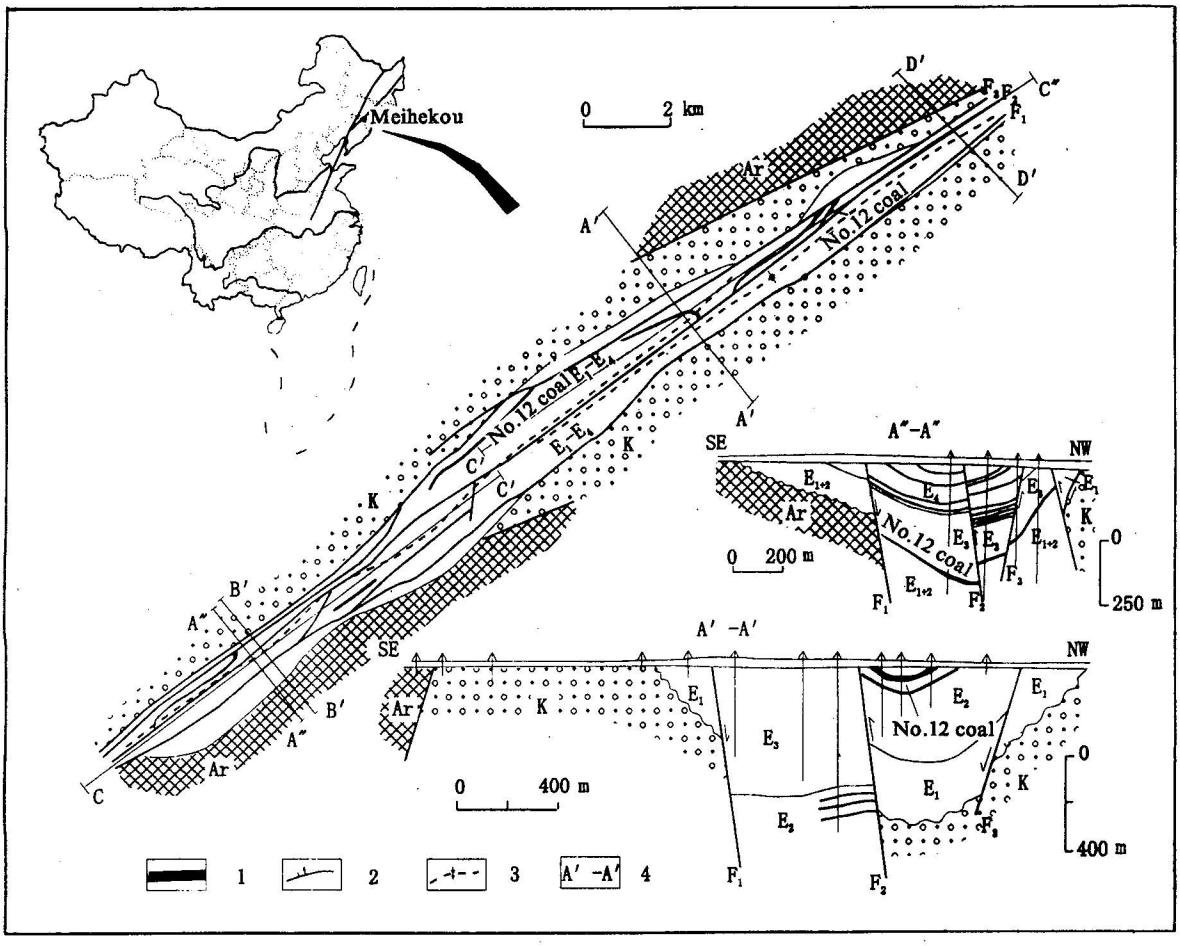

Fig. 1. Geological sketch map of the Meihekou basin.

1. Coal seams; 2. fault; 3. syncline axis; 4. location of sections.

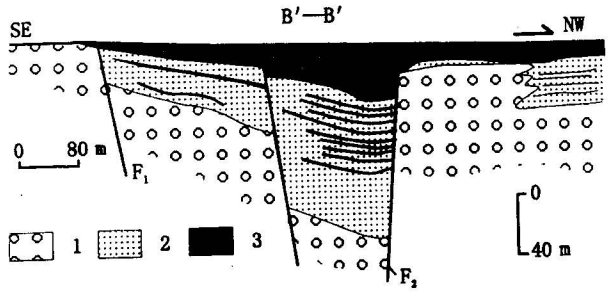

Fig. 2. A depositional section of E_2 Member in the Meihekou basin (location of the section is shown in Fig. 1).

1. Alluvial fan; 2. shallow lake and fan delta; 3. coal seams.

side of the residual basin, causing the strata of footwall to be uplifted and eroded. The F_2 fault in the basin underwent multi stage activities. It shows as a syndepositional normal fault under the dextral transtension regime (Fig. 2), changs into an inversed or overthrust fault under the sinistral transpressional regime (Fig. 4), and was characterized by a strike-ship fault in the late basin deformation (Fig. 5).

2 Basin Filling Succession and Sequence Stratigraphy

2.1 Basin filling succession

The overall sedimentary filling succession of the Meihekou basin is similar to the filling model of the late Mesozoic faulted basin in Northeast China (Li Sitian et al., 1988) (Fig. 6). It can also be divided into 5 mem-

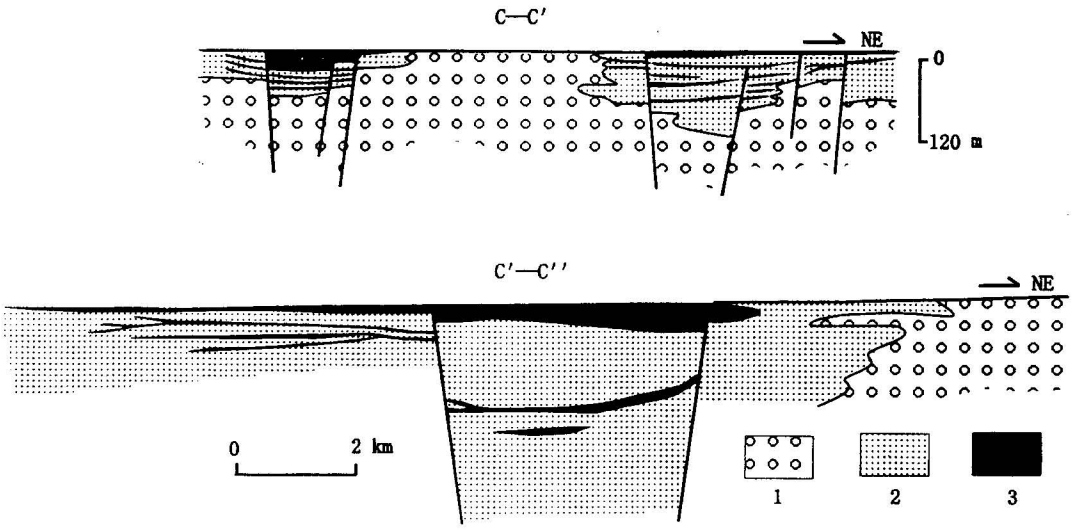

Fig. 3. Depositional sections of E_2 Member in the Meihekou basin (location of the sections is shown in Fig. 1).
1. Alluvial fan; 2. shallow lake and fan delta; 3. coal seams.

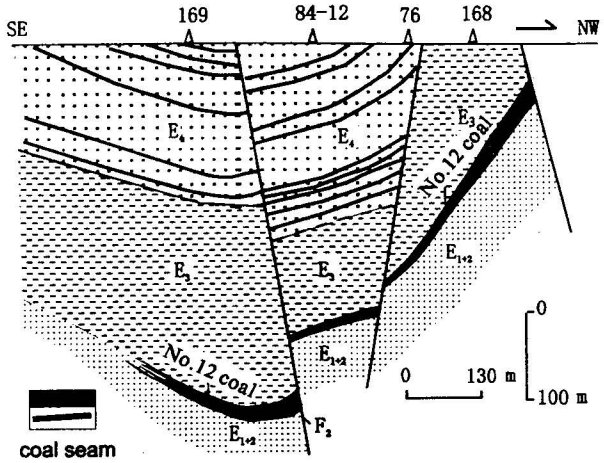

Fig. 4. A tectonic section of the Meihekou basin (magnification of section A″–A″ in Fig. 1).

bers from the lower to the upper:

(1) The lower coarse clastic member (E_1): This member, about 65–200 m, consists of conglomerate and gravel-bearing coarse sandstone from the alluvial fan system. Thick-bedded to massive mudflow sediments, with pooyly sorted and rounded pebbles (grain size generally 1–6 cm, partly exceeding 10 cm), are developed in the lower part. Thin-bedded sandstone and sandy gravel sheetflood sediments in parallel bedding and graded bedding are locally developed. This sedimentary association is characterized by fining-upward in grain size, thinning-upward in thickness and more obvious upward sediment differentiation. In the upper part, sediments of the alluvial fan delta braided channel and fan delta are locally developed.

(2) The main coal-bearing member (E_2): This member consists of shallow lake sediments and coal seams (90–230 m thick), and can be clearly divided into 2 parts. The lower part is dominated by shallow lake sediments, consisting of carbonaceous siltstone and mudstone interbedded with thin coal seams, sandstone and conglomerate representing flooding shallow water gravity flow. The thickness of sandstone and conglomerate is generally 0.5–2 m. A rhythmic succession with unequal thickness (with a thin fine clastic bed and a thick coarse clastic bed) is developed in the conglomerate. There are wave bedding and gentle wave bedding in the sandstone. Horizontal bedding is developed in the carbonaceous mudstone and siltstone, which contain fragments of fossil plants and locally animal fossils. The thin coal seams, with a linear structure and a high ash content, may be the product of the heterochthonous accumulation of the peat bog. The upper part of this member is mainly made up of coal seams. The thickness of the coal seams is generally 8–25 m, up to 50 m locally. The alluvial fan and fan delta sediments still exist on the margin of the basin.

(3) The oil-bearing mudstone member (E_3): This

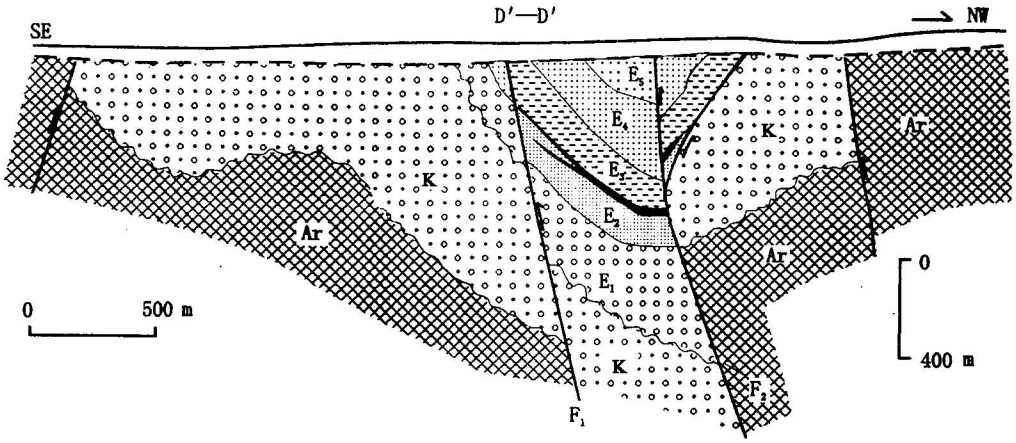

Fig. 5. A tectonic section of the Meihekou basin (location of section is shown in Fig. 1).

Stratigraphy		Basin filling succession	Depositional evolution	Sequence stratigraphy: Depositional system	System tract	Sequence	Tectonic sequence	Tectonic evolution	Regional tectonic setting
Q		Quaternary		Shallow lake and fluvial plain	LST	II_A	II	Inherited rifting	Palaeogene rifting
Meihekou Group	E_5	Upper coarse and fine clastic member 163—255 m		Alluvial fan					
	E_4	Upper coal-bearing member 140—285 m		Swamp and alluvial braided plain	HST	I_C	I	Tectonic mutation	Transpressional regime
				Shallow lake, fan delta and braided plain	LST				
	E_3	Oil-bearing mudstone member 58—190 m		Fan delta	HST	I_B		Biggest rifting	Transtensional regime
				Deep lake, turbidity flow system and marginal subaqatic fan	TST				
	E_2	Main coal-bearing member 90—230 m		Shallow lake, swamp and fan delta	HST	I_A		Accelerated rifting	
				Shallow lake and marginal fan					
	E_1	Lower coarse clastic member 65—200 m		Fan delta	TST			Initial rifting	
				Alluvial-diluvial fan	LST				
K		Sandstone and conglomerate	Basin basement						

Fig. 6. Sequence stratigraphy and sedimentary filling succession of the Meihekou basin.

member consists of relatively deep lake sediments (58–190 m thick). The deep-lake mudstone contains rich fresh-water animal fossils and well-preserved fossil leaves and generally bears oil, with oil content up to 3–6%. Thin turbidites with wave bedded and small cross-bedded fine sandstone (generally 0.2–0.5 m thick) and thin conglomerate are interlayered in the deep-lake mudstone.

(4) The upper coal-bearing member (E_4): This member is formed by fan delta sediments and coal seams (totalling 140–285 m thick). The fan delta sediments are made up of sandstones of various grain sizes. In the lower part, the fan delta front facies is well developed and made up of coarsening-upward prograding units. Those prograding units increase in thickness upward and transform gradually from the relatively deep water fan delta system into the shallow water fan delta system. Peat bog is poorly developed and the coal seams thus formed are thin and varied greatly. In the upper part, the fan delta is mainly made up of the shallow-water fan delta and alluvial braided plain. The peat bog is well developed, so the coal seams are thicker than those in the lower part.

(5) The upper coarse and fine clastic member (E_5): This member is composed of sandstone, conglomerate and green mudstone and is only locally conserved (163–255 m in residual thickness).

Compared with the filling model of the late Mesozoic basin in Northeast China, the thickness of the filling sequence of the Meihekou basin is smaller, the layer of relatively deep lake facies is relatively thin and the main coal seams lie lying just in the lower part of the deep-lake member.

2.2 Sequence stratigraphic units

The filling sequence of the Meihekou basin is divided into two tectonic sequences according to its filling characteristics and regional tectonic evolution. The filling thickness of tectonic sequence I is 700 m. That of the remnants of tectonic sequence II ranges from 163–255 m. Tectonic sequence I is under the tectonic setting of the early transtension and the late transpression, and can be further divided into three sequences, I_A, I_B and I_C (Fig. 6). The superface of I_A is the top of the main coal seam (No. 12 coal), which is characterized by the abandonment of peat bog and rapid expansion of the deep lake; that of I_B is the transform surface of the transtensional-transpressional regimes featured by the lake shrinkage and rapid progradation of the fan delta; and that of I_C is the subface of the Episode-II rifting, characterized by abandonment of the peat bog and development of the river and alluvial fan system. Sequences I_A and I_B were formed under the transtensional setting. Sequence I_A is made up of the lowstand system tract (LST), the middle transgressive system tract (TST) and the upper highstand system tract (HST). The lowstand system tract consists of the alluvial and dilurvial systems and almost fills up the whole basin. The transgressive system tract consists of the shallow lake and fan delta (retrogradational sequence), and the highstand system tract consists of the shallow lake, peat bog and marginal fan delta. Sequence I_B is made up of the transgressive system tract and highstand system tract. The transgressive system tract consists of the deep lake and turbidity flow system and marginal subaquatic fan. The highstand system tract consists mainly of the fan delta deposits (gradational sequence). Sequence I_C was formed in the transpressional tectonic background, consisting of a lowstand system tract and highstand system tract. The former consists mainly of the shallow lake, fan delta and braided plain, while the latter, mainly of the peat bog and alluvail braided plain.

3 Characteristics of the Coal Accumulating Processes

Coal accumulation in the Meihekou basin occurred during the accelerated rifting of the transtensional regime and the late tectonic transformation of the transpressional regime. Coal accumulation of most fault basins in Northeast China also occurred in the same period. The main coals in most faulted basins in Northeast China, however, occurred in the tectonic transformation stage from transextensional regime to transpressional regime (Li Sitian et al., 1988), whereas those in the Meihekou basin occurred during the accelerated rifting of a transtensional regime. The Fushun basin along this fault belt has the same feature (Zhuang Xinguo et al., 1993). This may be related to the basin's scale. Because the scale of basins in the linear fracture zone is relatively small, it is easy for the highstand

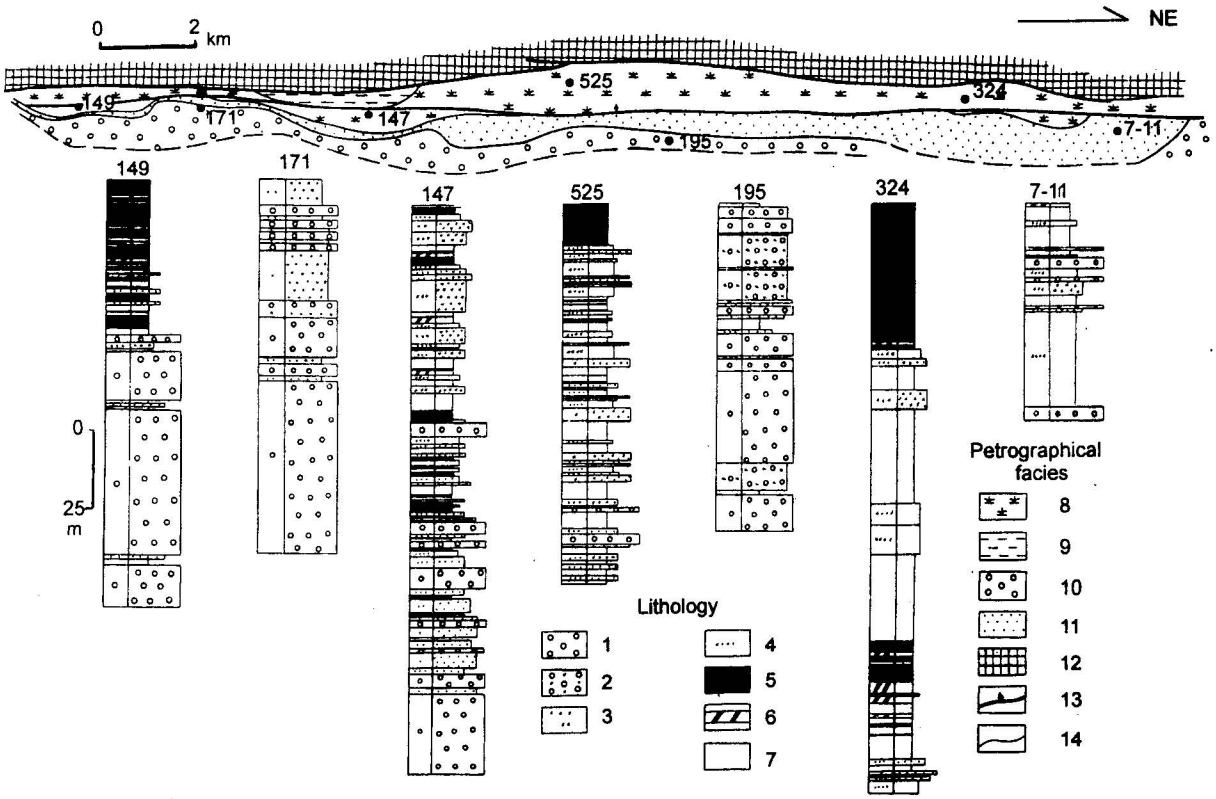

Fig. 7. Palaeosedimentary environment of Member E_2 of the Meihekou basin.

1. Conglomerate; 2. sandy conglomerate; 3. sandstone; 4. siltstone; 5. coal seam; 6. carbonaceous mudstone; 7. mudstone; 8. peat bog; 9. shallow lake; 10. alluvial fan; 11. transitional belt of the fan front; 12. denudation area; 13. synsedimentary fault; 14. postsedimentary fault.

shallow lake and fan delta to form (with poorly developed braided fan delta plains) due to the good accordance between the material supply and the tectonic subsidence under the transtensional setting. In the late tectonic transformation in a transpressional regime, however, a highstand fan delta system is easy to form in which the braided fan delta plain is developed.

The coal seams were developed mainly on the basis of the shallow lake in the accelerating stage under the transtensional regime (Fig. 7). The peat bog spread widely and only part of the area was covered by the residual shallow lake. The thickness of the coal seams was controlled by the fault-block activity (Figs. 2 and 3) and thick coal seams are distributed in the down-faulted trough (generally 10–25 m, maximum over 50 m). The relatively thin coal seams were distributed on the fault uplift (generally <10 m). The coal seams were developed mainly on the base of the braided fan delta plain during the later tectonic transformation under the transpressional regime. The range of the peat bog is relatively small and the formed coals are thin (generally <2 m) and was controlled by frequent lateral migration of the fan delta.

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