E&P NOTE

The discovery and significance of a sedimentary hiatus within the Carboniferous Taiyuan Formation, northeastern Ordos Basin, China

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ABSTRACT

The sandstone at the base of the Upper Pennsylvanian Taiyuan Formation (Ct₁) is a prominent gas reservoir in the Daniudi gas field, northeastern Ordos Basin, China. Logs, cores, thin sections, outcrops, scanning electron microscopy, and three-dimensional seismic data are used to delineate sedimentary facies and to divide the succession into sequence-stratigraphic units.

The gas-bearing coarse-grained sandstone is interpreted as a fluvial-dominated incised-valley fill. A sedimentary hiatus documented for the first time in the study area forms the sequence boundary between the Lower Pennsylvanian Taiyuan Formation (Ct₁) and Upper Pennsylvanian (Ct₂). The hiatus and overlying incised-valley fill can be observed at the Heidaigou outcrop, where the presence of bauxite indicates a period of subaerial weathering. The incised-valley fill and hiatus can also be found through the outcrop correlation of Xipo, Chengjiazhuang, Qiaotou, and Heidaigou at the eastern margin of Ordos Basin. Two types of basinward and two types of landward facies shifts are identified between Ct₁ and Ct₂ based on core observations and cross-well profiles analysis to demonstrate abrupt facies change and punctuation. Further

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evidence for a hiatus is provided by an onlap at this surface on the seismic data.

INTRODUCTION

Geologic Background

The Ordos Basin is located on the western North China plate. It is composed of six structural units: Yimeng uplift, Western Edge overthrust belt, Tianhuan depression, Yishan ramp, Jinxin flexural belt, and Weibei uplift. The Daniudi gas field, the focus of this article, which is located in the northeastern Yishan ramp, has an area of approximately 775 mi² (~2003 km²; Figure 1).

The Carboniferous succession is composed of the Benxi Formation (Mississippian) and the overlying Taiyuan Formation (Pennsylvanian). The Permian Shanxi Formation in turn overlies the Taiyuan Formation. The Taiyuan Formation provides one of the most important gas plays in the Daniudi gas field. Gas production from a single well in Ct₂ ranges from $1.77 \times 10^5$ to $35.3 \times 10^5$ ft³/d ($0.5 \times 10^4$–$10 \times 10^4$ m³/d).

The thickness of the Taiyuan Formation ranges from 65.6 to 295.3 ft (20–90 m), and the formation consists of the Pennsylvanian Taiyuan Formation member 1 (Ct₁) and member 2 (Ct₂; Figure 2). Member Ct₁ mainly consists of medium-to coarse-grained quartz sandstone, thick coal beds, and mudstones, whereas Ct₂ consists mainly of conglomerate and gravelly sandstones, as well as coarse-, medium-, and fine-grained sandstones; limestones; coal beds; and mudstones. During the late Paleozoic, siliciclastic sediments were derived mainly from the Yimeng uplift in the northern part of the Ordos Basin (Liu et al., 2003).

Member Ct₁ contains a prominent barrier island-lagoon system facies association (Chen et al., 2004; Hao et al., 2007). Wang et al. (2007) suggested that the depositional environment had changed to barrier shoreline deposits and braided delta-plain deposits by late Ct₂. Others have proposed that Ct₂ is composed of deltaic deposits (Fu et al., 2003) or thin shallow-marine limestones and thick fluvial-deltaic deposits (Li et al., 1995; Liu, 1998). Based on the study of fusulinid-bearing strata, Guo and Liu (1999) suggested that abrupt high-frequency sea level changes were characteristic of the late Paleozoic and that the Taiyuan Formation contains a record of these relative sea level changes.
The contact between Ct1 and Ct2 has previously been believed to be continuous and lacking any hiatus.

In this article, a sequence boundary (hiatus) with an overlying incised-valley fill is identified at the contact, based on outcrop and seismic interpretation. This interpretation is consistent with the abrupt sedimentary facies shifts between Ct1 and Ct2.

**Database and Methodology**

This work was conducted using cores and 200 thin sections from 20 wells, together with well logs and gas production data from 120 wells. Three outcrops were also examined, along with a nearly 772 mi² (2000 km²) of three-dimensional seismic data. Detailed core and thin section descriptions, together with the precise measurement of...
well-exposed outcrops, allow us to identify sedimentary microfacies within the Taiyuan Formation. Outcrop samples were analyzed by scanning electron microscopy (SEM) using a Quanta 200 SEM and energy-dispersive x-ray spectroscopy (EDAX) to determine crystal morphology and compositions. Well-tie correlations and seismic interpretation enable interpretation of onlap at the sequence boundary and the along-strike and down-dip geometries of the overlying incised valley.
SEDIMENTARY FACIES

Sedimentary Facies of Ct1

Deposits in Ct1 are mainly coal bed; mudstone; and fine-, medium-, and coarse-grained sandstone (Figure 3A). The lower part of Ct1 (Figure 3A), which ranges from 8448.2 to 8467.8 ft (2575–2581 m), consists of fine-grained sandstone deposits in a fining-upward succession. Grains are subangular, moderately to well sorted, and have a 92% content of quartz. This succession begins with parallel beddings, followed by flaser and lenticular beddings (Figure 3B). These characteristics indicate a
strong tidal influence and the succession may represent tidal channel deposits.

The middle part of $Ct_1$ (Figure 3A), ranging from 8412 to 8445 ft (2564–2574 m), is separated from the lower part by an approximately 3 ft (1 m)-thick black lagoonal mudstone. This section is mainly composed of gravelly coarse-grained sandstone and medium- to coarse-grained sandstone. The grains are subangular and well sorted, with extremely high quartz content (almost 99%). The succession fines upward from gravelly coarse-grained sandstone at the base to medium- to fine-grained sandstone. Parallel bedding, low-angle cross-bedding (Figure 3C), and trough cross-bedding (Figure 3D) are present, and these sediments may also be tidal channel deposits.

The uppermost deposits of $Ct_1$, ranging from 8383 to 8412 ft (2555–2564 m), are composed of thick coal beds and thin black carbonaceous mudstones (Figure 3E).

The predominant sedimentary environment of the Taiyuan Formation is the barrier shoreline (Chen et al., 2004; Hao et al., 2007; Wang et al., 2007), and the main sedimentary facies in $Ct_1$ are those of barrier islands, tidal channels, and lagoons.

Tidal channels are recognized by their fine-grained cross-stratified character. Some cross-stratification suggests bidirectional paleocurrents (Figures 4A, 5A). Sands are well sorted, and the quartz content of tidal channel sand bodies is more than 95% (Figure 6A).
The barrier island facies is mainly composed of eolian trough cross-bedded medium-grained sandstones, moderately to well sorted, and with a coarsening-upward vertical motif (Figure 4B). Morton et al. (2000) reported well-sorted sandstones in the barrier islands of the western Gulf of Mexico. A significant characteristic of the barrier island deposits within Ct1 is their high compositional maturity with a high average quartz content, which is more than 95% (Figure 6B).

Lagoon and swamp deposits form the major fine-grained components in Ct1. They are mainly composed of coal beds and carbonaceous mudstone (Figures 2, 3). Dark lagoonal mudstones contain pyrite (Figure 4G, H). Thick coal beds are common in the upper part of Ct1 (Figures 3; 4I, J), and have thicknesses ranging from 20 to 53 ft (6–16 m).

**Sedimentary Facies of Ct2**

The deposits in Ct2 can also be divided into three parts. A lower interval of coarse-grained sandstone is overlain by an interval of mudstone and limestone, followed by an upper section composed of mudstone, coal bed, and fine-grained sandstone (Figure 2).

The lower part of Ct2 from 8301 to 8383 ft (2530–2555 m) is composed of multiple fining-upward successions (Figure 3). Each succession begins with a scour surface at its base, indicating an erosion of underlying strata. In the first fining-upward succession from 8333 to 8383 ft (2540–2555 m), a 32.8-ft (10-m) thick gravelly coarse-grained sandstone with trough cross-bedding is overlain by 16 ft (5 m) of medium- to coarse-grained sandstone with parallel bedding. The gravelly coarse-grained sandstone is subangular and moderately...
well sorted and has 88% quartz. Gravel clasts of 4 to 6 mm diameter account for 20 to 50% of the gravelly coarse sandstone. Two other fining-upward cycles from 8301 to 8333 ft (2530–2540 m) also have scour surfaces at their base. Trough cross-beddings are the major sedimentary structures (Figure 3F). These coarse-grained sandstones, which make up the lower part of Ct₂, are overlain by thick mudstone (Figure 3A) or limestone (Figure 2). These are in turn overlain by the upper part of Ct₂, which is mainly composed of thin coalbed, mudstone (Figure 3), siltstone, and fine-grained sandstone (Figure 2).

These coarse-grained sediments are interpreted as braided stream depositions that lie directly on the underlying coal beds or carbonaceous mudstones of Ct₁ (Figures 2, 3, 4C, D). Some gravels contain high-angle cross strata and erosional surfaces, indicating that the sediments were deposited from strong, confined tractive currents that were able to move subaqueous gravel dunes (Figure 4C). The fining-upward character of these sharp-based fluvial deposits can also be recognized in outcrops (Figure 5B).

In addition, trough cross-bedding, plane-parallel lamination, wedge cross-bedding, and planar cross-bedding are observed in both the cores (Figure 4E, 6).
F) and in outcrops (Figure 5C, D). The gamma-ray log of the braided stream deposits is typically cylinder shaped (9167–9211 ft [2794–2808 m]; D49, Figure 2).

Many erosional surfaces are observed within these braided stream deposits. The braided stream sand bodies of Ct2 directly erode the coal bed and carbonaceous mudstone of the underlying Ct1 (Figure 7A, B, C). The high relief of the scour surfaces would have been caused by erosion (Figure 7B, C). Some scour surfaces within the braided stream gravels also erode fine- and medium-grained sandstone of Ct1 (Figure 7D).

In thin sections, matrix in the braided stream clastic sediments is high (as much as 20–30%). Grains are angular and poorly sorted, indicating short transport distances (Figure 6C, D). In contrast, the clastic particles in the barrier shoreline setting are affected by tides, waves, and winds and are therefore better sorted and more rounded (Figure 6A, B).

The widespread shelf mudstones and limestones that overlie the braided stream deposits indicate a sea level rise.

The limestones and mudstones are in turn overlain by thin units of coal beds and associated carbonaceous mudstones and silty sandstone, all of which probably represent swamp deposits.

Stacking Patterns and Lateral Trends

The stacking patterns by which facies of Ct2 overlie those of Ct1 are of four types: barrier island overlain by braided stream, swamp overlain by braided stream, swamp overlain by shelf limestone, and swamp overlain by shelf mudstone.

The first two stacking patterns, basinward facies shift, barrier island overlain by braided stream and swamp overlain by braided stream, indicate an abrupt progradation and sea level falls. Carbonaceous mudstones and coal beds overlain by conglomerate or coarse-grained sandstones at an erosive contact are common in the study area (Figures 7A, B, C; 8). Fine-grained sandstone of the barrier island facies eroded by gravels can be seen in cores (Figure 7D).

In contrast, the second pair of stacking patterns, represented by the occurrence of shelf mudstone or limestone overlying swamp deposits, indicates a landward facies shift caused by a relative sea level rise. These relationships can be seen in the crosswell profile (Figure 8B, C).

The vertical facies stacking patterns and lateral facies trends shown in Figure 8 illustrate that the Ct2 braided stream sediments eroded the underlying coal beds and carbonaceous mudstones of Ct1 over a relatively limited area and are overlain...
Figure 8. Cross-well profiles showing facies stacking patterns, lateral trends, thickness variation of coal beds, and incised-valley geometry. (A) Cross-well profile oriented northeast to southwest within incised valley. (B) and (C) Cross-well profiles oriented east to west are perpendicular to the incised valley. See Figure 1C for location. FFS = first flooding surface; MFS = maximum flooding surface; LST = lowstand systems tract; TST = transgressive systems tract; HST = highstand systems tract; GR = gamma ray; RLLD = resistivity; AC = acoustic.
in turn by shelf limestone or mudstone. In contrast, the swamp of Ct1 was overlain directly by shelf limestone or mudstone of Ct2 across a wide area where the braided stream facies of Ct2 is absent. It is therefore possible that the braided stream facies of Ct2 has eroded over a part of the study area and that a hiatus developed between Ct1 and Ct2. We will investigate this possibility further in the following section based on outcrop observations, outcrop correlation, seismic interpretation, and coalbed thickness changes.

SEDIMENTARY HIATUS AND INCISED VALLEY

Outcrop Evidence

An outcrop at Heidaigou located in the northeastern part of the study area (see Figure 1A for location) shows that two distinct types of lithologic contacts between Ct1 and Ct2 exist.

The first type of contact involves a coal bed overlain by thick coarse-grained sandstone, with a 2-in. (6-cm)-thick variegated mudstone developed between them (Figure 9A). Ferruginous film occurs on the sole of the coarse-grained sandstone (Figure 9B), suggesting that the mudstone had experienced weathering.

At the second type of contact, the coal bed is overlain by approximately 19 ft (~6 m) of variegated mudstone (Figure 10). Three samples were collected from these variegated mudstones at different outcrop locations for laboratory analysis (Figure 10). The samples were tested at 22° and at a humidity of 40% using a Quanta 200 SEM and EDAX spectrum instrument. The high Al2O3 component and presence of SiO2 indicate bauxite (Table 1). Sample S1, collected from brown bauxite (Figure 10), has a relatively high Fe2O3 content. The existence of bauxite and its components provide strong evidence for weathering and for the presence of a hiatus between Ct1 and Ct2.

Outcrop Correlation

Stratigraphic correlation along the eastern margin of the Ordos Basin connects the outcrops at
Xipo, Chengjiazhuang, Qiaotou, and Heidaigou (Figure 11; see Figure 1A for location). Four limestone beds—Guanjiaya, Baode, Gancaoshan, and Heilongguan—are developed in Taiyuan Formation, particularly in the southern part of the basin. Toward Qiaotou and Heidaigou, which are close to the Daniudi gas field, the Guanjiaya limestone in Ct1 is eroded by coarse-grained Qiaotou sandstone of Ct2 and is even entirely missing. This erosional relationship constitutes further evidence for a hiatus between Ct1 and Ct2.

**Seismic Evidence**

Seismic data image a large channel with a concave base and onlapping channel fill (Figure 12; see SS’ in Figure 1C for location). This feature is interpreted as an incised valley. The width of the valley is approximately 5.3 mi (~8.5 km), and the fill thickness is approximately 131 ft (~40 m). The channel incision erodes underlying Ct1. The concave base of the incision can therefore be interpreted as a sequence boundary between Ct1 and Ct2.

**Thickness of Coal Bed**

A review of coalbed thicknesses within the upper part of Ct1 shows that coal beds thinner than 26.2 ft (8 m) are distributed along a northeastern trend.
within the area where the incised valley and braided streams occurs (Figure 13). Beyond this area, the thicknesses of coal beds become greater, ranging from 26.2 to 52.5 ft (8–16 m).

Well correlation profiles BB′ and CC′ are perpendicular to the trend of the incised valley (Figure 8B, C). Incised-valley fills of Ct2 erode coal beds of underlying Ct1. Coal beds are thinner beneath the incised valley relative to other areas. For example, coal beds near well D47 are thinner than those near wells D44 and D36 on profile BB′ (Figure 8B). Similarly, coal beds near wells D18

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**Figure 11.** Stratigraphic correlation cross section of the Taiyuan Formation, east margin of Ordos Basin (modified from Chen, 1989). Four limestone beds exist: bed 1 (Guanjiaya limestone), bed 2 (Baode limestone), bed 3 (Gancaoshan limestone), and bed 4 (Heilongguan limestone). The bed 1 limestone in Ct1 is well developed in the south but is eroded northward toward Qiaotou and Heidaigou by overlying Qiaotou sandstone. See Figure 1A for location.

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**Figure 12.** Seismic image of the incised valley in the Daniudi gas field showing its concave base and the onlapping channel fill. See SS′ in Figure 1C for location.
and D21 are thinner than those near wells D15 and D20 on profile CC' (Figure 8C). In addition, well correlation profile AA', which is parallel to the incised valley, demonstrates that the coal bed beneath the valley is thin and that its thickness changes little (Figure 8A). We suggest that the thinning of coal beds over the study area is caused by valley erosion during a relative sea level fall.

Figure 13. Isopach map of coal beds in Ct1. Coal beds with thicknesses less than 26.2 ft [<8 m] are distributed along a northeasterly trend associated with the incised valley.
Valley Geometry

Incised-valley sandstone deposits are developed within a relative narrow area in a lenticular form in east to west profiles (Figure 8B, C). The sandstone that developed around well D47 is nearly 105 ft (32 m) thick; it gradually decreases in thickness toward well D55 and even pinches out toward well

Figure 14. Isopach map of sandstones and conglomerates in the lowstand systems tract of Ct2. The incised valley is 4 to 6 mi (7–9 km) wide and approximately 40 mi (~65 km) long and is oriented from northeast to southwest.
D36 (Figure 8B). An isopach map of the sandstones and conglomerates in the lower part of Ct2 clearly shows the geometry of the incised valley (Figure 14). The thickness of the sandstones and conglomerates ranges from 16 ft (5 m) outside the valley to 115 ft (35 m) within the valley. The width of the valley is approximately 4 to 6 mi (∼7–9 km) and it extends approximately 40 mi (∼65 km) from the northeast to the southwest across the study area. The concave shape of the valley-fill sandstone can be seen on both well profiles (Figure 8B, C). In addition, as shown on Figure 8A, sandstone thickness decreases from the northeast (∼89 ft [∼27 m] in well D35) to the southwest (∼62 ft [∼19 m] in well D49 and ∼28 ft [∼9 m] in well D50), indicating a possible paleocurrent from northeast to southwest (Figure 14).

SEQUENCE-STRATIGRAPHIC MODEL

A sequence-stratigraphic model for the Taiyuan Formation can be built based on sedimentary facies, their stacking character, and the presence of the hiatus. The Taiyuan Formation was deposited during a period of approximately 10 m.y. and can be divided into two third-order sequences: sequence Ct1 and sequence Ct2 (Figure 2). Sequence Ct1 consists of only the lowstand systems tract (LST); the transgressive systems tract (TST) and the highstand systems tract (HST) have been eroded (Figure 15). Sequence Ct2 contains all three systems tracts: LST, TST, and HST. Because of the changes in relative sea level and depositional setting, the sedimentary facies within the systems tracts differ greatly from one another (Figure 15). We have mapped the distribution of facies based on the analysis of sediments from individual wells, sequence-stratigraphic division (Figure 2), and cross-well profile analysis for facies vertical stacking patterns and lateral trends (Figure 8).

Sequence Ct1

A barrier shoreline depositional system, including barrier islands, a tidal channel, and a lagoon, is developed in the lower part of Ct1 (Figure 16). The barrier islands extended in a northeast-southwest direction and were approximately 3 to 4 mi (5–7 km) wide. Tidal flow entered the lagoon through the southeast-northwest-oriented tidal channel. The lagoon mainly occupied the northwestern part of the study area. This depositional system is interpreted as having developed during falling relative sea level and represents an early LST.

Coal accumulation is controlled by the tectonic setting, depositional environment, paleoclimate, and availability of plant material (Han and Yang, 1980). Areas in which subsidence rates are either too low or too high are not favorable for coal accumulation (Shao et al., 2003). Bohacs and Suter (1997) suggested that significant volumes...
of terrigenous organic matter can be preserved to form coals only when the overall increase in accommodation is approximately equal to the production rate of peat. This is most likely within the LST and HST, when rates of sea level change are moderate.

Figure 16. Sedimentary facies of the early lowstand systems tract in Ct1. The barrier islands extended in a northeast-southwest direction and were approximately 3 to 4 mi (∼5–7 km) wide. The lagoon was mainly located in the northwestern part of the study area.
Thick coal beds that overlie the barrier shoreline deposits developed widely at the top of Ct₁ as the lagoon became swampy (Figures 2, 3, 8). The overall increase in accommodation must therefore have approximately equaled the production rate of peat at that time. This aggradational interval represents the late LST.

**Sequence Ct₂**

**Lowstand Systems Tract**
The sedimentary hiatus between Ct₁ and Ct₂ is accompanied by an incised valley at the base of Ct₂. The thick incised-valley fill, mostly conglomerates and coarse- to fine-grained sandstones, is strong evidence of an LST. The incised valley is oriented in a northeast-southwest direction (Figure 17). The strata outside the incised valley (beneath the hiatus) are exposed coal beds of Ct₁. Because of the erosion by the braided stream system, coal beds below the valley are thinner than those across the rest of the area (Figures 8, 13).

**Transgressive Systems Tract and Highstand Systems Tract**
During the relative sea level rise associated with TST, accommodation increased, the input of terrigenous siliciclastic sediments decreased, and limestone was deposited (Figure 2). The limestone, which is equivalent to the Baode limestone in Figure 11, occurs mostly in the southwestern part of the study area, suggesting that the transgression was from southwest to northeast (Figure 18). The base of the limestone represents the beginning of the transgression (Zhang et al., 2009). This transgressive surface is marked by a coal bed overlain by shelf limestone and mudstone (Figure 8B, C).

Similar evidence for marine transgression and formation of a TST is found where the middle Pennsylvanian Bartlesville sandstone in Oklahoma, interpreted as an incised-valley fill, is overlain by the Inola limestone (Ye and Kerr, 2000). In addition, Breyer (1995) suggested that the development of crinoidal limestones in Beaver County, Oklahoma, represented an increase of relative water depth and the establishment of open marine conditions.

The siltstone, sandstone, mudstone, and thin coal beds forming the upper part of Ct₂ suggest a greater rate of sediment supply than that during the deposition of the underlying mudstone and limestone. We infer that the sea level had begun to fall and that this part of Ct₂ represents HST deposition.

**SIGNIFICANCE OF THE MID-TAIYUAN HIATUS AND OVERLYING FILL**
The incised valley, which formed during the mid-Taiyuan time of relative sea level fall and was filled with braided stream sediments that deposited as sea level subsequently rose, holds important gas reserves. This part of the succession is therefore critical to exploration and production. As such, the valley is typical of incised valleys worldwide, which tends to be important petroleum exploration targets despite forming volumetrically small parts of the stratigraphic record (Van Wagoner et al., 1990; Dalrymple et al., 1994; Posamentier and Allen, 1999). For example, in northeastern Oklahoma, hydrocarbon resources are mostly controlled by incised-valley geometry, and high-quality reservoir sandstones in the incised valley contain approximately two-thirds of the oil reserves in place (Ye and Kerr, 2000).

The thick coal beds and carbonaceous mudstones in Ct₁ are the main source rocks (Li et al., 2009; Wang et al., 2011). The thick sandstone bodies within the incised valley are effective reservoir rocks, and the transgressive limestone or mudstone that overlies the incised valley forms a good seal. Therefore, the Taiyuan Formation has an excellent combination of gas source, reservoir, and seal.

Almost all the existing wells producing from Ct₂ are confined within the incised-valley fill (Figure 17). Therefore, the LST holds most of the reservoirs of Ct₂. In contrast, the TST contains only limestone and mudstone, whereas the HST contains only thin sand bodies. The thick coarse clastics (gravels or sandstones) of the LST braided stream deposits, confined within the incised valley, continue to represent the optimal targets for the next stage of gas exploration. Furthermore, the geometry of the incised valley is a key control on reservoir distribution.
Figure 17. Sedimentary facies and distribution of gas productivity in the lowstand systems tract (LST) of Ct2. The braided stream is oriented northeast to southwest. This figure also shows that gas production wells are confined within the incised valley.
The incised valley is predicted to extend farther northeastward and southwestward outside the study area (the Daniudi gas field), and more gas reservoirs can therefore be expected along this trend.

**CONCLUSIONS**

A new sequence-stratigraphic perspective is offered for the Carboniferous Taiyuan Formation of
the Daniudi gas field in the Ordos Basin. An erosional hiatus within the Taiyuan Formation is documented for the first time and represents a sequence boundary between the lower (Ct₁) and upper (Ct₂) members of the formation. Numerous observations provide evidence for the existence of an erosional hiatus: (1) clear erosional contact relationships, (2) the presence of ferruginous sediments at the base of the sandstones, (3) variegated bauxite observed at outcrops along the boundary, (4) the concave valley shape on seismic profiles, (5) variations in coaledickness within the top of Ct₁ (thicker outside the valley), and (6) the common basinward facies shift between Ct₁ and Ct₂ indicative of falling relative sea level above the erosional surface. The sedimentary environment of the LST of Ct₁ is that of a barrier shoreline overlain by thick swamp coal beds. The coal beds were then partly eroded and the sedimentary hiatus was created at the sequence boundary. The sequence boundary is in turn overlain by the lowstand incised-valley fill of Ct₂, interpreted from seismic data and outcrop correlation, consisting of braided stream deposits identified from cores, well logs, and thin section descriptions. The TST of the overlying Ct₂ is dominated by limestone and mudstone and the overlying HST contains swamp mudstone, thin sandstone, and coal beds.

The coarse clastics in the incised valley are the main reservoirs in the study area, and the valley geometry controls the distribution of gas reservoirs. The coarse clastics of the incised-valley fill continue to be probable targets for future gas explorations both inside the study area and elsewhere in the Ordos Basin.

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