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Sedimentary Provenance Analysis of Palaeocene in the X Sag, East China Sea Shelf Basin

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Abstract: The analysis of sedimentary provenance characteristics is the premise of sedimentary system analysis. At present, the understanding of sedimentary provenance is not unified in the exploration and development of Lishui Sag. To solve this problem, in this paper, we used the clastic components composition and the major element oxides to analyze the tectonic setting in provenance area, the analysis of paleogeomorphology, heavy minerals, mudstone color index and paleocurrent indicated by seismic reflection characteristics were used to analyze the provenance direction. Through the analysis of clastic components composition, it is considered that the provenance of Paleocene sedimentary system in the X sag mainly comes from the areas of Recycled Orogenic, Dissected Arc and Transitional Arc, and the analysis of major element oxides shows that the provenance tectonic setting and type of Paleocene sedimentary system in the X sag is mainly active continental margin and island arc, these two conclusions are basically consistent. The paleogeomorphology, heavy minerals, mudstone color index and seismic reflection characteristics analysis shows that the provenance direction in the sedimentary period mainly comes from the west, southwest of Minzhe Uplift and East of Yandang Uplift. Different provenance areas provide substantial sediments basis for the development of sedimentary facies in the study area.

Keywords: Tectonic Setting of Provenance Area, Provenance Direction, Palaeocene, X Sag, East China Sea Shelf Basin

1. Introduction

Provenance analysis is the premise of determining the sedimentary system and is of great significance to the exploration and development of oil and gas resources. According to the products of sedimentation, it is an important content of provenance analysis to infer the petrological characteristics of the source rocks in the clastic provenance area, as well as the tectonic setting and provenance direction at the time of sedimentation, it is also important to analyze tectonic evolution and distribution of sedimentary systems [1-4].

The mineral composition, geochemical composition and distribution form of sediments play an important role in provenance analysis and tectonic setting research. In recent years, predecessors have carried out various studies on the Paleocene stratigraphic sediment sources in the X Sag. For example, Chen et al analyzed the provenance area properties of the East and West Sub Sags of the X Sag through clastic zircon U-Pb dating. It is considered that the sediments source of the X West Sub Sag mainly comes from the Minzhe Uplift area in the west of the sag, mainly volcanic rocks debris, containing a small number of intrusive rocks debris and metamorphic rocks debris. The sediments source of X East Sub Sag mainly comes from the Yushan Uplift area in the east of the sag, with sedimentary rocks and intrusive rocks debris as the main sediments source. Based on the provenance analysis of the X 36-1 tectonic area, Yang et al believe that the provenance of the upper Paleocene mainly comes from the Minzhe Uplift Belt in the west of the sag and the Lingfeng Uplift Belt in the middle. Different provenance areas control the development and distribution of sedimentary system through fault activity and sea level rise and fall. It can be seen that the provenance characteristics of the study area are still controversial, and the previous research methods are relatively single, pay less attention to the provenance tectonic setting, and the understanding is controversial. Therefore, based on the previous research results, through the analysis of clastic components, major element oxides, drilling rock debris, heavy minerals and seismic reflection characteristics, this paper makes a detailed analysis on the provenance tectonic setting and direction in the study area, which provides a basis for determining the types of sedimentary facies under different Paleocene provenance systems in the X Sag.

2. Data and Methods

This paper was based on core geochemical data, rock debris and seismic data derived from 18 wells in the X Sag. The core geochemical data data were used to analyze the clastic components of rock framework and major elements distribution of X Sag to identify tectonic setting in provenance area. The core geochemical data, rock debris and seismic data were used to analyze sedimentary paleogeomorphology, seismic reflection characteristics, heavy minerals distribution and Mudstone color index distribution of X Sag to identify provenance direction. In particular, these data and methods will help us to understand the basic characteristics of sedimentary system provenance.

3. Geological Background

The East China Sea Shelf Basin (ECSSB) is located on the continental shelf of the East China Sea, adjacent to the Minzhe Uplift in the West and the Diaoyu Island Uplift Belt in the East, it distributed in NE-SW direction, the ECSSB is the largest offshore oil and gas basin in China [5]. The X Sag is a typical Cenozoic faulted basin with the characteristics of east fault and west overlap, developed on the basement of Mesozoic residual basin. It is located in the southwest of the ECSSB, adjacent to the Zhemin Up-lift in the west, Qiantang Sag and Yushan Uplift in the north, and separated from Fu-zhou Sag in the east by Yandang Uplift. It can be divided into five secondary tectonic units: X West Sub Sag, X East Sub Sag, Linfeng Uplift, X South Sub Sag and X South Uplift (Figure 1-a) [5-7]. The sag is mainly controlled by the NE-SW multi-stage fault system. The study area is mainly distributed near the East-West Sub Sag and Lingfeng Uplift. At present, there are 18 wells in the study area, mainly located near the West Sub Sag, East Sub Sag and Lingfeng Uplift (Figure 1-b).

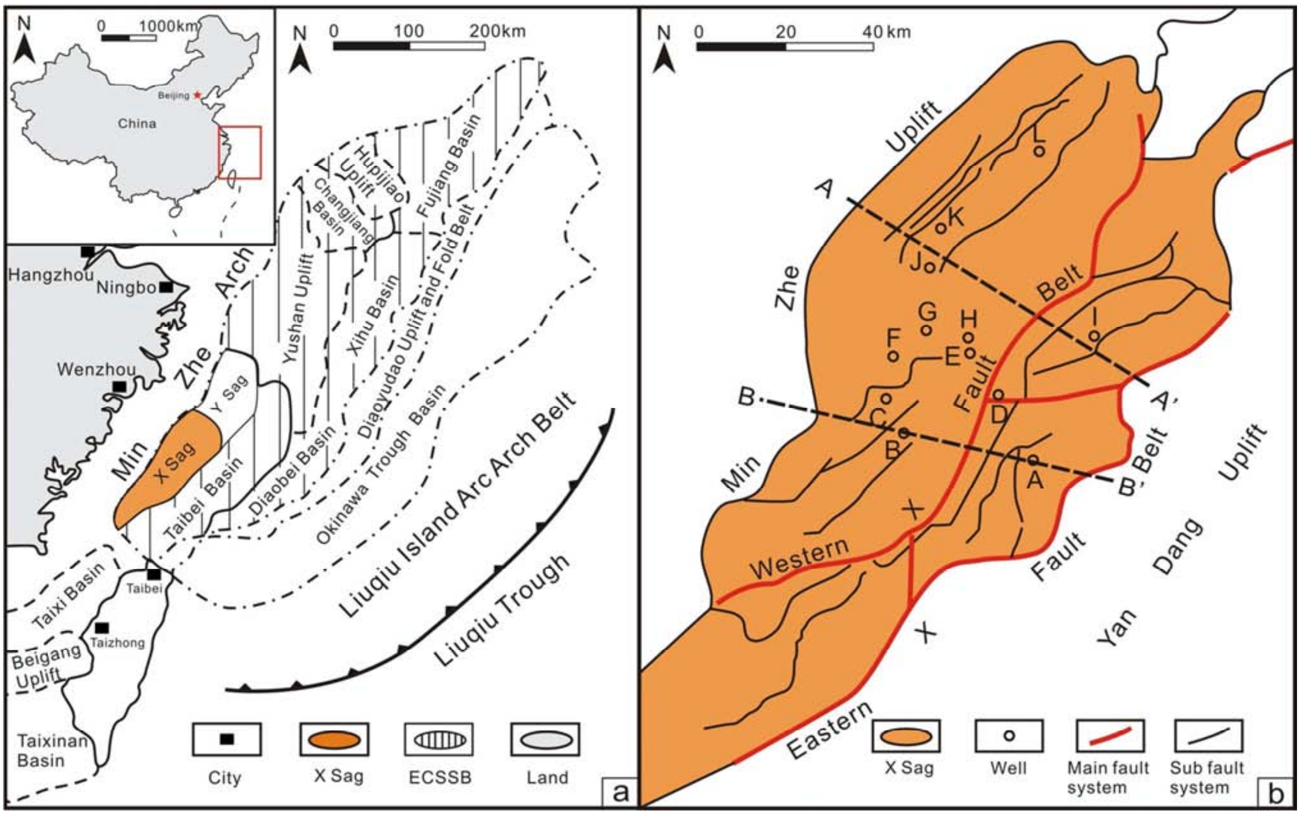

Figure 1. *(a) Tectonic location of the X Sag; (b) Structural units and well positions of the X Sag [8].*

The tectonic geological background of X Sag is consistent with that of the ECSSB and can be roughly divided into five tectonic evolution stages, including: initial fault depression stage of Late Cretaceous, strong fault depression stage from Late Cre-taceous to Paleocene, fault depression transition stage at the end of Paleocene, depres-sion stage from early Eocene to late Eocene and regional subsidence stage from Neo-gene to Quaternary (Figure 2-a) [9-14]. Drilling data show that the basement of X Sag is Mesozoic extrusive rock, intrusive rock and Mesoproterozoic metamorphic rock. At present, the sedimentary stratum encountered from old to new mainly include Cre-taceous, Paleogene, Neogene and Quaternary [10-13]. The target stratum of this study is mainly the Y Formation, L Formation and M Formation of Paleocene in Paleogene, in which L Formation is divided into the upper L Formation and the lower L Formation, and M Formation is divided into the upper M Formation and the lower M Formation (Figure 2-b).

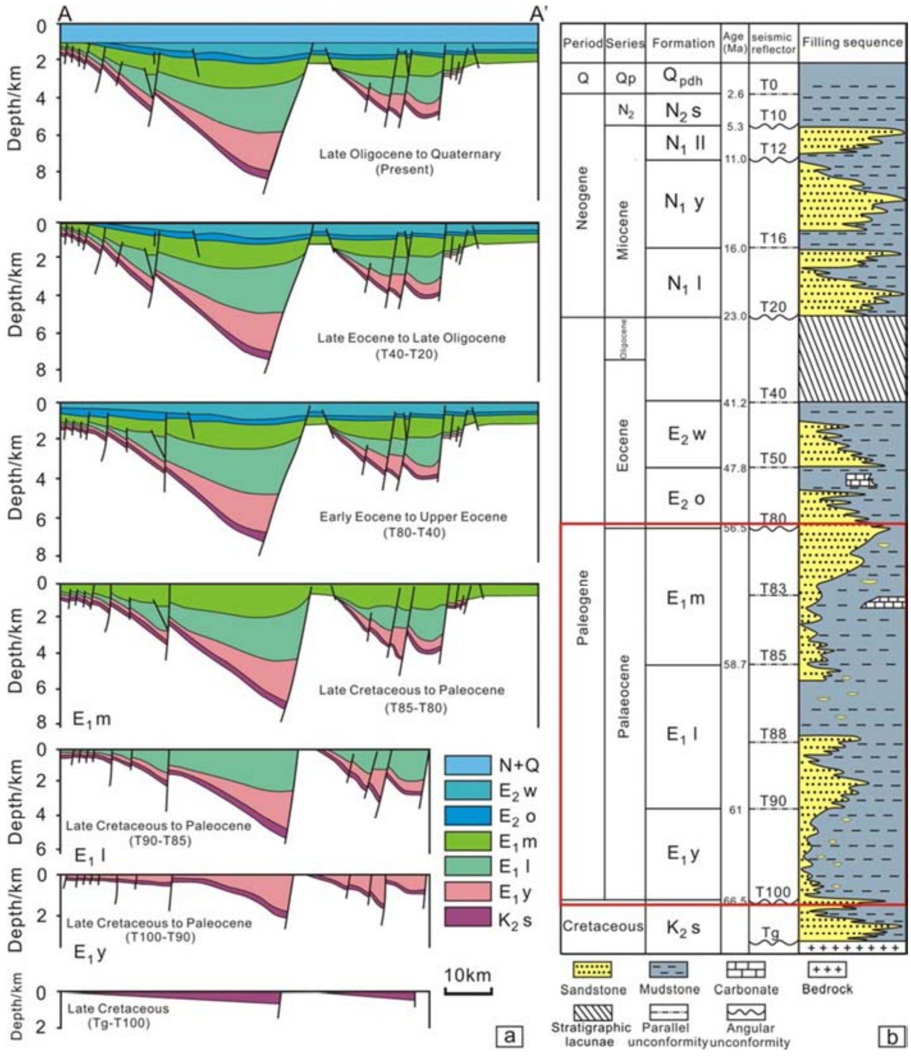

Figure 2. *(a) Evolutionary history of tectonics in X Sag; (b) Sequence stratigraphic chart of X Sag [8, 11].*

4. Results

4.1. Analysis of Tectonic Setting in Provenance Area

4.1.1. Clastic Components of Rock Framework and Tectonic Setting

Dickinson et al (1985) believe that the contents of quartz (Q), feldspar (F) and rock debris (L) in the framework components of clastic rocks can reflect the tectonic setting of the provenance area, and established the Dickinson triangle chart [15]. In this study, the thin sections of Paleocene rock samples in X sag were identified in detail under the microscope, and the QFL chart also was established by using the framework components of clastic rocks. It can be seen from the figure that the samples in the whole area of X sag basically fall in the provenance areas of the Recycled Orogenic, Dissected Arc and Transitional Arc, in which the provenance tectonic setting of different groups of strata is different. Among them, the Y Formation is mainly the source of Recycled Orogenic, L Formation is mainly the provenance of Recycled Orogenic, Dissected Arc and Transitional Arc, M

Formation is basically consistent with the whole region, indicating that there are certain unstable characteristics, orogeny and magmatic activity in the provenance area around X sag during Paleocene (Figure 3). In addition, it can be seen from the distribution of well sample points that the Well I in the East Sub Sag is basically located in the Recycled Orogenic area and near the Dissected Arc, and the rock debris composition is metamorphic rock, which also reflects this feature. Well C in the West Sub Sag is also located in the area of the Recycled Orogenic area at different times, and E, H and other wells near the middle area of the sag are consistent with the characteristics of the whole region, but the distribution is more concentrated, the rock debris are mainly volcanic rocks, which also reflects this feature.

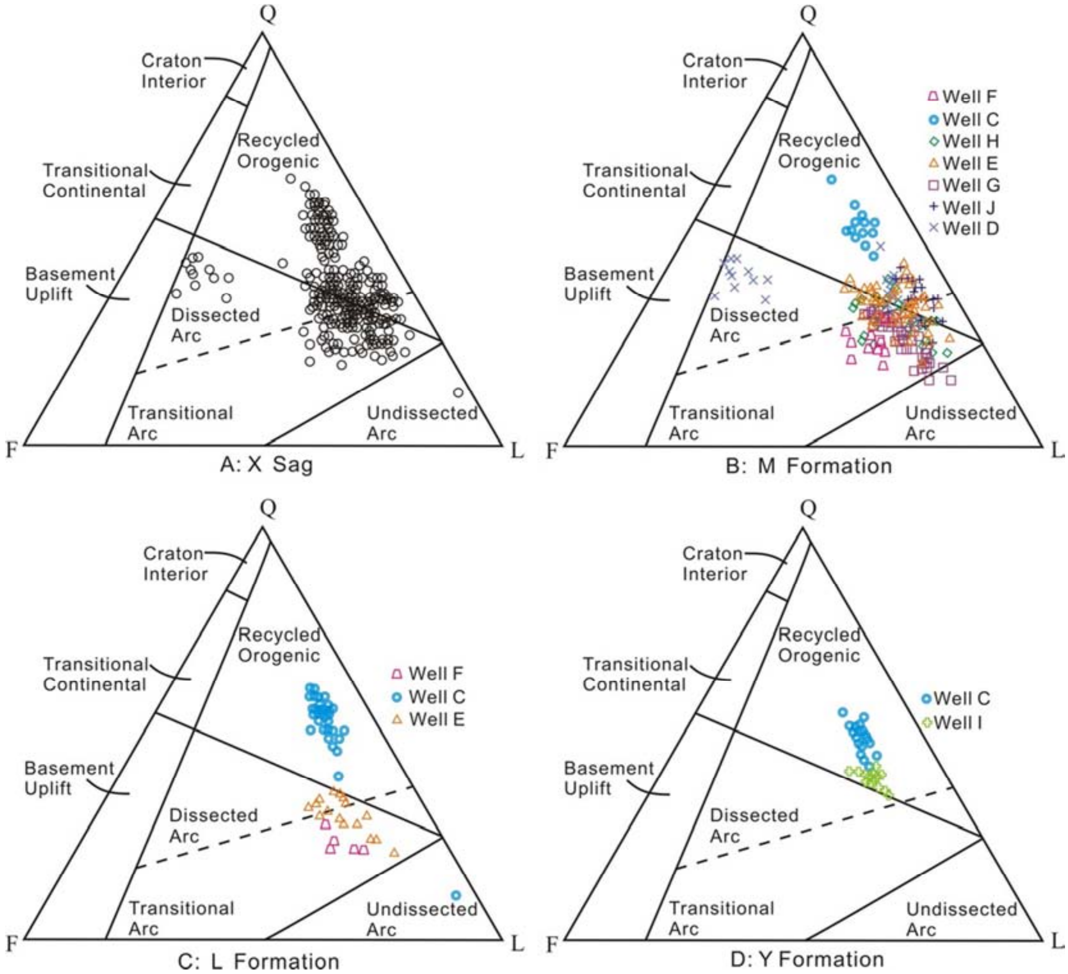

Figure 3. *QFL diagram of Paleocene in X Sag (Modified from Dickinson, 1985).*

4.1.2. Major Elements and Tectonic Setting of Provenance Area

In addition to the framework clastic components of clastic rocks, some geochemical indexes can also be used to analyze the tectonic setting of the provenance area. Bhatia (1983) and Roser (1986) proposed to use the geochemical characteristics of major elements of clastic rocks to distinguish the tectonic setting of the source area [16, 17]. The oxides of major elements such as Fe_2O_3, TiO_2, K_2O, Na_2O, SiO_2, CaO, Al_2O_3 can be used as indicators to establish a discrimination chart to distinguish the tectonic stting and type of provenance area. This method can complement the clastic rock debris composition method [18-21]. This study also identified and counted the major elements of each well samples in the sag, and established the discrimination chart between the major elements and the tectonic environment of the provenance area in the study area. It can be seen from the chart that the sample points in the SiO_2 - K_2O/Na_2O chart in the study area mainly fall in the ACM area, a small part in the ARC and PM area, and the sample points in the SiO_2/Al_2O_3 - K_2O/Na_2O chart mainly fall in the ACM area, some of them fall in areas PM, A1 and A2, indicating that the tectonic setting of the provenance area is basically in the active continental margin and island arc setting (Figure 4 A-B). In the (Fe_2O_3+MgO) - TiO_2, (Fe_2O_3+MgO) - Al_2O_3/SiO_2, (Fe_2O_3+MgO) - K_2O/Na_2O and (Fe_2O_3+MgO) - Al_2O_3/(CaO+Na_2O) chart, the sample points mainly fall in areas b and c, and a small amount fall in areas a and d, these indicators show that the tectonic setting of the provenance area is the active continental margin and island arc bsetting (Figure 4 A-F), from the distribution of each formation of strata, they are distributed in each area. Therefore, according to the oxide judgment of major elements, the tectonic setting and type of Paleocene stratigraphic provenance area in X sag are mainly active continental margin and continental island arc area, in which the sedimentary periods of different formations are slightly different, which is basically consistent with the discrimination results of clastic rock components.

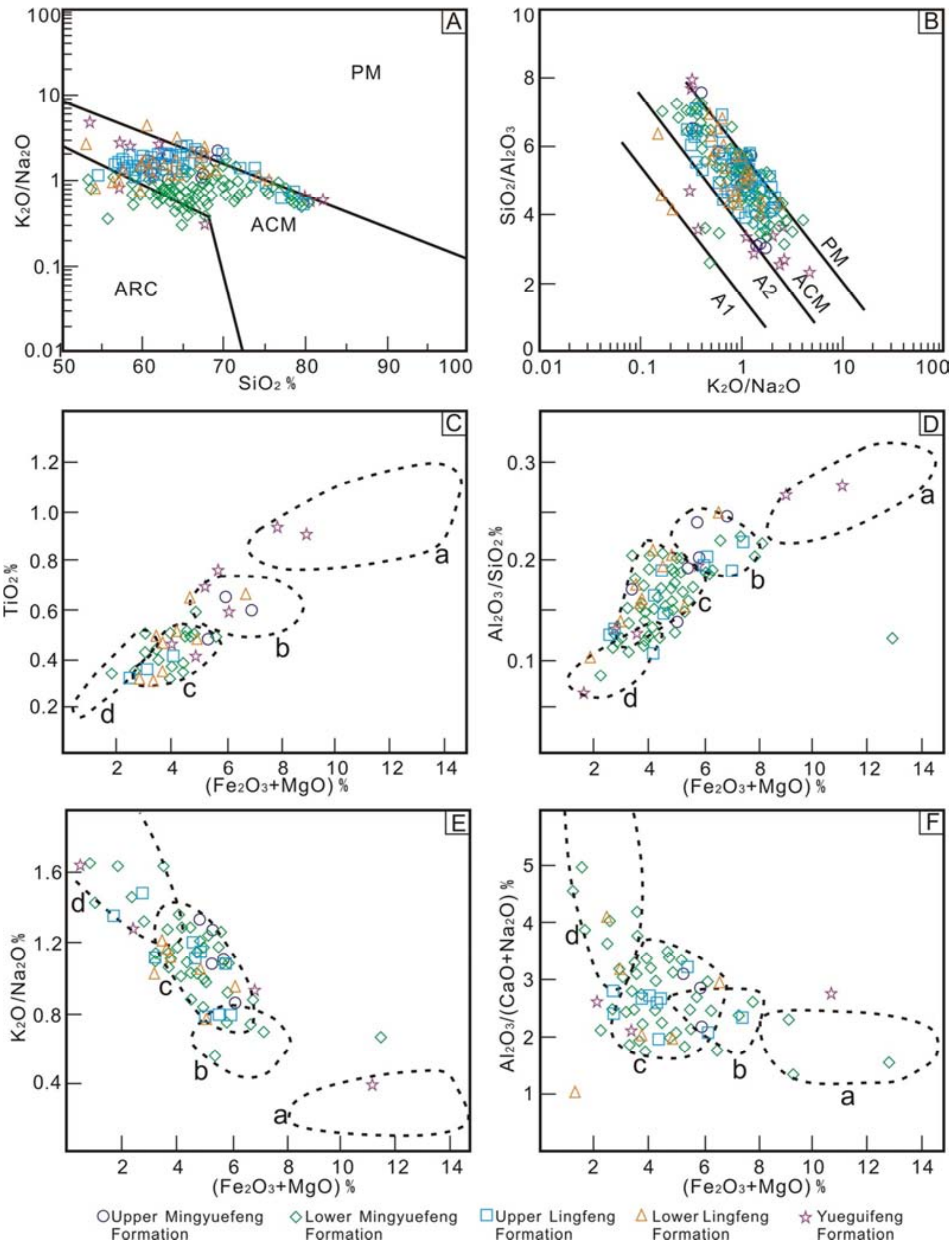

Figure 4. *Discriminant map of main elements and tectonic environment of provenance in X Sag,*

A, B according to Roser et al, 1986, PM: Passive margins, ACM: Active continental margin, ARC: Oceanic/continental island arc, A2: Evolved arc setting, felsitic-plutonic detritus, A1: Arc setting, basaltic and andesitic detritus, C, D, E, F according to Bhatia, 1983, a: Oceanic island arc, b: Continental island arc, c: Active continental margin, d: Passive margins

4.2. Provenance Direction

Reconstruction of sedimentary paleogeomorphology and utilization of some special indicators in sediments can help us trace provenance orientation and analyze provenance factors affecting the development of sedimentary system [20-22].

4.2.1. Sedimentary Paleogeomorphology and Provenance Direction

Paleogeomorphology is an important factor affecting the development and distribution of sedimentary system, and paleogeomorphology analysis is the premise of sedimentary system characterization. This study reconstructed the sedimentary paleogeomorphology and analyzed the provenance direction on the basis of precise structural interpretation [23, 24].

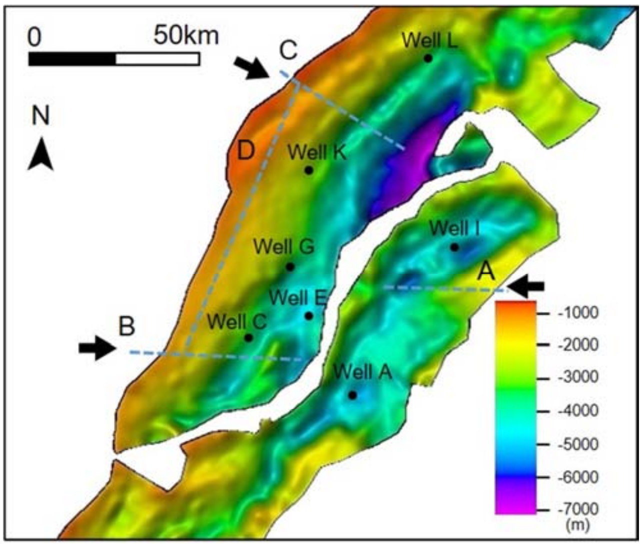

Figure 5. *Sedimentary palaeogeomorphic map of Palaeocene in X Sag.*

Controlled by the NE-SW direction main fault, X sag is divided into the East Sub Sag and West Sub Sag. A N-S direction strike slip main fault is developed in the middle of the sag, forming Lingfeng Uplift. In the later stage, the uplift and decline of Lingfeng Uplift affect the distribution pattern of structural units in the whole sag. At the initial stage of sedimentation, affected by regional tectonic movement, the sag is composed of several independent and scattered small fault depressions. In the later stage, with the strengthening of tectonic movement, the sag forms an east-west sub sag pattern with the expansion of the basin, Lingfeng Uplift is gradually formed, the East Sub Sag and West Sub Sag are basically not communicated with each other, and the sedimentary center of the West Sub Sag is mainly distributed in the north and near the Lingfeng Uplift, the Minzhe Uplift Belt and southwest area is relatively gentle, the sedimentary center of the East Sub Sag is close to the central part of the sub sag. With local fault activities and the deposition of the L Formation strata, the paleogeographic characteristics of the sedimentary strata have changed to some extent. During the deposition period of M Formation, the sedimentary strata gradually covered the Lingfeng Uplift, and then Oujiang movement occurred and the fault depression stage ended, the stratum development tends to be gentle. According to the paleogeomorphic characteristics and evolution process of Paleocene in X Sag, the sediment source is likely to come from the Minzhe Uplift and Yandang Uplift. The Lingfeng Uplift in the middle of the sag is unstable and small, so it is difficult to provide a relatively stable semiments source (Figure 5).

4.2.2. Seismic Reflection Characteristics and Provenance Direction

Seismic reflection parameters are 2D or 3D seismic response characteristics formed by sedimentary facies or geological body in a certain sedimentary environment on seismic profile or data volume [22, 23]. The accurate identification of seismic reflection characteristics with important sedimentary significance in a certain seismic stratigraphic unit plays an important role in the analysis of sedimentary process, erosion and paleogeomorphology. At the same time, it can also help us judge the direction of paleocurrent and sediments source. Common seismic reflection parameters mainly include amplitude, frequency, continuity, internal reflection structure and external geometric form of the unit. The internal structure is mainly parallel, divergent, progradation and wavy structure, and the external forms are mainly sheet, wedge, moundy, lenticular and filling, which can be used to effectively distinguish the source direction [23, 25-27]. Especially for the characteristics of X Sag and similar a lack of drlling areas, the reflection characteristics of seismic profile can be fully used to synthesize the paleocurrent direction and analyze the provenance direction.

Through the analysis of 3D seismic and 2D survey line seismic profiles in X Sag, it is found that the seismic internal reflection characteristics in X Sag can see obvious reflection structures such as parallel, divergent and progradation, as well as lenticular and moundy shapes. Among them, the progradation reflection characteristics in the seismic profile indicate paleocurrent, and lenticular reflection indicates the possible existence of fluvial channel. Therefore, through the analysis of a large number of seismic sections and the synthesis of paleocurrent direction, it can be seen that the provenance in the study area mainly comes from the west and southwest of Minzhe uplift and Yandang Uplift (Figure 6). (Positions of A-D were shown in Figure 5).

4.2.3. Heavy Minerals Distribution and Provenance Direction

Heavy minerals are important indicators for analyzing the provenance direction, under similar hydrodynamic environment and diagenetic evolution conditions, stable heavy minerals have the characteristics of strong weathering resistance, wide distribution range and relatively high content far away from the source area, unstable heavy minerals have weak weathering resistance, small distribution range and relatively reduced far away from the source area, by analyzing the ratio change and combination relationship between them, the provenance direction and area properties can be restored [22-24].

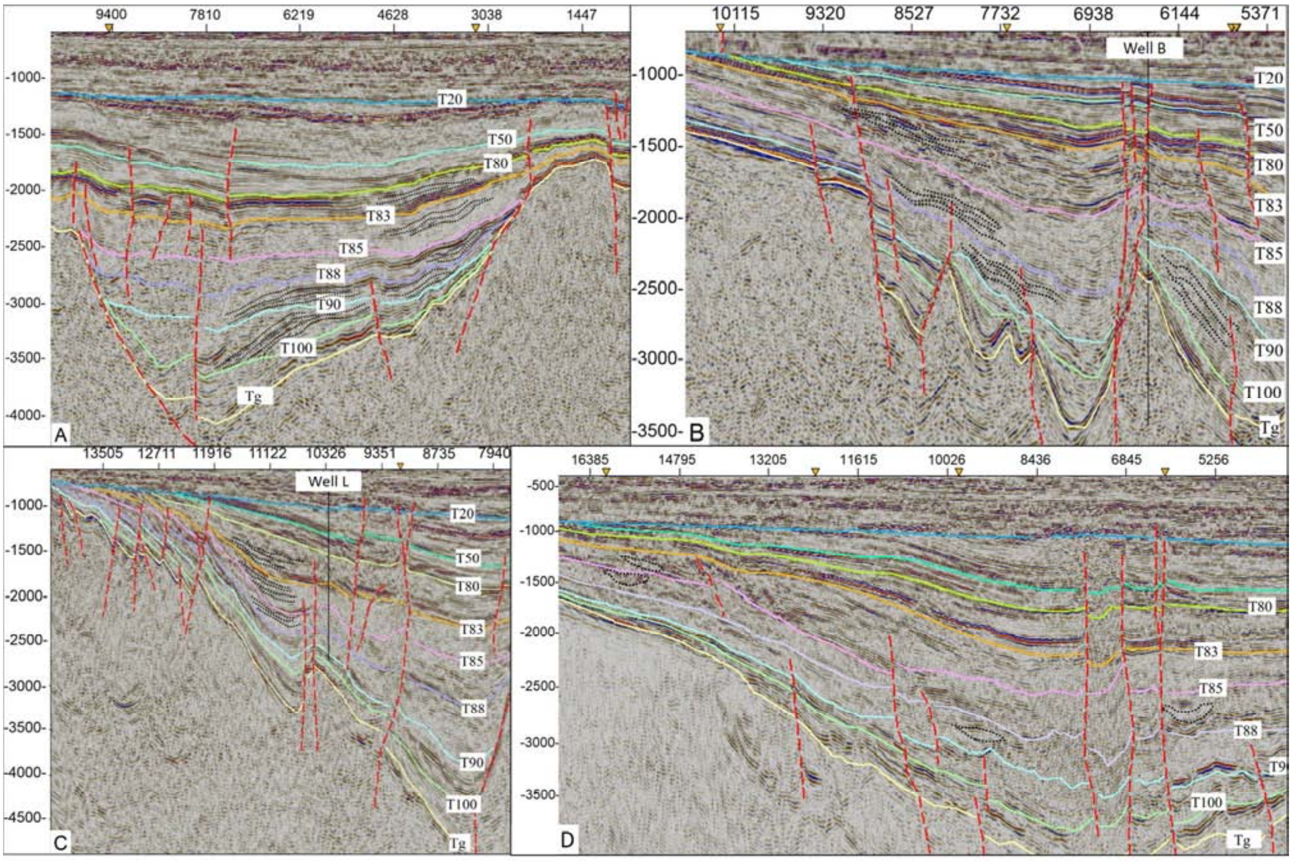

Figure 6. Seismic reflection characteristics of Paleocene in X Sag.

In this study, in the process of analyzing the provenance direction of Paleocene strata in X Sag by using drilling data, the ZTR index of heavy minerals and the combination characteristics of heavy minerals in the study area are analyzed. The ZTR index is the ratio of stable heavy minerals to transparent heavy minerals, ZTR= [(zircon+tourmaline+ rutile)/(zircon+tourmaline+rutile+grenatite+garnet+sphene+ mica+epidote+barite)] × 100% [22-24].

Through the thin section identification and statistical analysis of more than 80 samples from 8 wells in X Sag, it is known that more than 20 types of heavy minerals are developed in Paleocene sandstone, including zircon, tourmaline, garnet, epidote, magnetite, perovskite, limonite, pyrite, barite and anatase, and the content of different minerals varies greatly.

The index analysis shows that the ZTR index of well G is 0.84, the ZTR index of well C is 0.8, the ZTR index of well B is 0.87, the ZTR index of well H is 0.96, the ZTR index of well D is 0.87, and the ZTR index of well I is 0.77. The content of stable heavy minerals gradually increases from Minzhe Uplift and Yandang Uplift to X Sag. It can be seen that the sediments source of X Sag mainly comes from Yandang Uplift in the east, Minzhe Uplift in Northwest and Southwest (Figure 7).

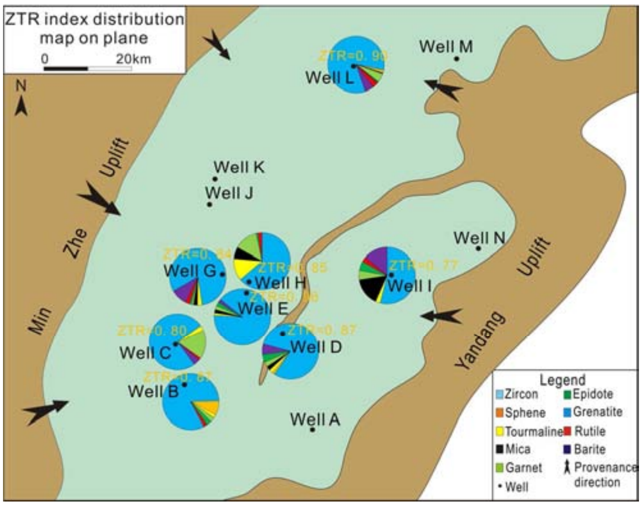

Figure 7. ZTR index plane distribution map of Paleocene in X Sag.

4.2.4. Mudstone Color Index and Provenance Direction

The color of sedimentary rocks, especially mudstone, can also play an important role in the analysis of paleoclimate and paleogeographic environment. The mudstone color index (Table 1) [22-24] can be obtained by dividing the mudstone color in each sequence by the total thickness of the corresponding stratum according to the oxidation-reduction degree.

Table 1. *Scale of mudstone color [22-24].*

Color	Black	Dark grey	Grey	Greyish-green	Light grey	Yellow	Brown	Dark brown	Red
Code	12	13	14	8	0	4,5	10,9	15	1, 2, 3, 11
Scale	-100%	-75%	-50%	-25%	0%	25%	50%	75%	100%

Through the calculation of mudstone color index of each well point in the target strata, it is found that the mudstone color value is larger, the oxidation degree is higher; on the contrary, the reduction degree is stronger. According to the contour map of mudstone color value of each formation in the study area, it can be seen that during the sedimentary period of M Formation, the study area mainly focuses on the primary color, and the mudstone color in the east is mainly negative, mainly grayish green mudstone, indicating that the sedimentary environment is a reducing environment. With the rise of Lingfeng Uplift, the distribution of mudstone color value is different, and the range of mudstone color value changes little, compared with M Formation, the upper and lower L Formation are basically the same, and the provenance comes from the west, southwest of Minzhe Uplift and East of Yandang Uplift (Figures 8-9).

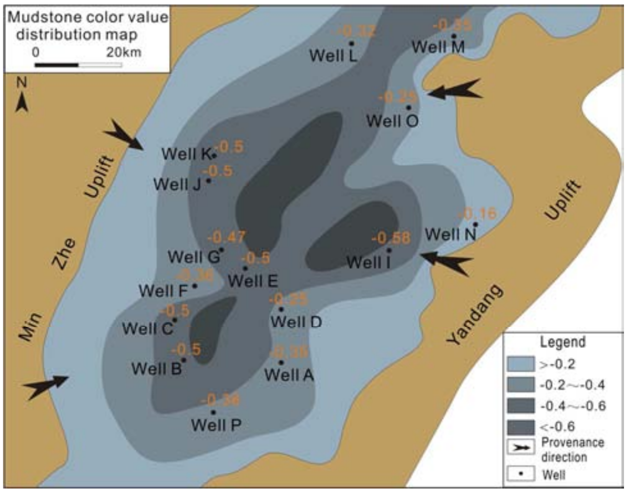

Figure 8. *Mudstone color value distribution map of M Formation in X Sag.*

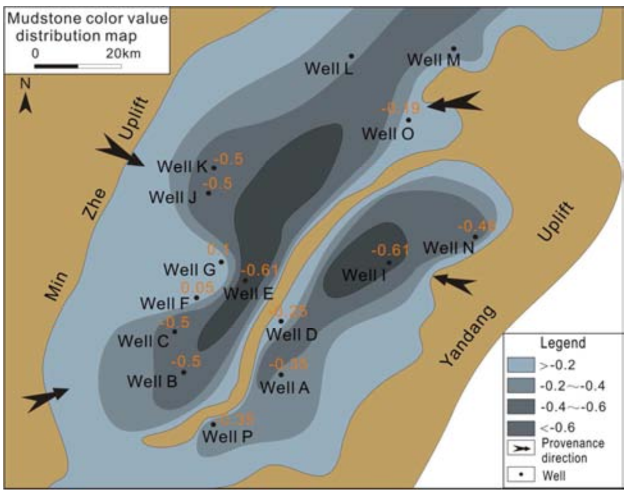

Figure 9. *Mudstone color value distribution map of L Formation in X Sag.*

5. Discussion

There are different methods that can be used in the process of analyzing sediment sources. For example, Chen et al (2017) analyzed the provenances of the sediments in the sub-sags in eastern and western X Sag through detrital zircon U-Pb dating, the results show that sediments in the west sub-sag were mostly sourced from Minzhe Uplift Zone in the western part of the Sag where volcanic rocks are predominant with some intrusive and metamorphic rocks [4]. In the previous analysis, the method is relatively simple, and the tectonic setting of the study area is not considered. Therefore, in this paper, we used the Dickinson triangle chart and the major element oxides chart to analyze the tectonic setting in provenance area. Dickinson's triangle chart method is based on the statistical data of clastic components of rock framework under the microscope to study the tectonic setting of the source area, it is widely used and convenient, such as Xia et al (2019) consider that the geochemical composition of sandstones in sedimentary basin plays an important role in the study of sedimentary provenance and tectonic settings and used Dickinson's triangle chart to analyze geochemical characteristics and geological implications of sandstones from the Yaojia Formation in Qianjiadian Uranium Deposit, Southern Songliao Basin [18]. When using Dickinson's triangle chart, it is necessary to accurately count various parameters of clastic components. The content of matrix or cement in the selected rock samples should be less than 25%, the calculation error should not exceed 5%, and the standard deviation of multiple statistical average values of rock samples should not exceed 10%. Even so, there are still many cases where the interpretation of provenance based on the discrimination diagram is inconsistent with the actual situation [28], which may be mainly due to the following aspects:

(1) Effect of mixture source

The discriminant diagram established by Dickinson only based on the provenance area properties of sandstone formed by direct and short-distance transportation of sediments into the basin, this relatively special situation is distinguished. The general situation is that in many sedimentary basins, the sandstone lithofacies have multiple provenances, and the sandstone facies formed along the collision suture zone and the active continental margin must have the nature of mixture provenance.

(2) Influence of secondary action

Weathering, transportation and diagenesis inevitably destroy the clastic components, which affects the reliability of the discrimination diagram. For example, the dissolution and metasomatism of clastic components will increase the abundance of quartzitic particles in the diagenetic process. Generally, the sandstone subjected to strong dissolution and metasomatism is not suitable for provenance analysis.

Therefore, the provenance discrimination diagram of sandstone clastic components is helpful to the analysis of the tectonic setting of the provenance area, but it must be combined with other geological evidence to draw a practical conclusion.

In addition, during the analysis of provenance direction in the study area, due to the erosion of Y Formation, the drilling in the study area rarely encountered it, and the seismic data obtained from this formation are also less. In the actual analysis process, a variety of methods should be comprehensively analyzed to increase the accuracy of the results.

6. Conclusion

Through the analysis of Paleocene stratigraphic provenance in X Sag, it is considered that:

(1) QFL chart is established by using clastic components, which shows that the Paleocene stratigraphic provenance in the X Sag mainly comes from the Recycled Orogenic, Dissected Arc and Transitional Arc.

(2) According to the oxide judgment of major elements, the provenance tectonic setting and type of Paleocene stratigraphic in the X Sag are mainly active continental margin and island arc area, in which the sedimentary periods of different formayions are slightly different, which is basically consistent with the discrimination results of clastic components.

(3) Paleogeomorphology, heavy minerals and mudstone color index and paleocurrent indicated by seismic reflection characteristics show that the provenance direction in the sedimentary period mainly comes from the west, southwest of Minzhe uplift and East of Yandang uplift.

Conflicts of Interest

The authors declare that they have no competing interests.

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References

[1] Zhao HG, Liu CY. (2003). Approaches and Prospects of Provenance Analysis. Acta Sedimentology Sinica, (03): 409-415.

[2] Wang YG. (2019). Development characteristics and regional background of igneous rocks in Lishui Sag. China Petroleum and Chemical Standards and Quality, 39 (09): 150-151.

[3] Yang YQ, Tian H, Liu DN, et al. (2003). Provenance Analysis of the Upper Paleocene in Lishui 36-1 Structure of Lishui Sag, East China Sea Shelf Basin. Journal of Palaeogeography, (02): 171-179.

[4] Chen CF, Zhong K, Zhong WL, et al. (2017). Provenance of sediments and its effects on reservoir physical properties in Lishui Sag, East China Sea Shelf Basin. Oil & Gas Geology, 38 (05): 963-972.

[5] Zhong K, Wang X, Zhang T, et al. (2019). Distribution of residual Mesozoic basins and their exploration potential in the western depression zone of East China Sea Shelf Basin. Marine Geology & Quaternary Geology, 39 (06): 41-51.

[6] Tian Y, Ye J, Yang B, et al. (2016). Hydrocarbon accumulation rule and exploration target optimization in Lishui Sag, East China Sea Continental Shelf Basin. Natural Gas Geoscience, 27 (04): 639-653.

[7] Zhang T, Zhang P, Zhang S, et al. (2015). Tectonic characteristics and evolution of the west depression belt of the East China Sea Shelf Basin. Marine Geology Frontiers, 31 (05): 1-7.

[8] Liu LL, Li Y, Dong HZ, Sun ZQ. (2020). Diagenesis and reservoir quality of Paleocene tight sandstones, Lishui Sag, East China Sea Shelf Basin. Journal of Petroleum Science and Engineering, 107615.

[9] Zhang M. (2015). The Condition of Hydrocarbon Accumulation and Enrichment Regulation of Paleocene Reservoirs in Lishui Sag, East China Sea Shelf Basin. Beijing Normal University, China.

[10] Sun Z. (2020). Sedimentary Facies and Development Characteristics of the Paleocene in Lishui Sag, East China Sea Shelf Basin. Beijing Normal University, China.

[11] Jia C, Xia B, Wang H, Zhang S. (2006). Characteristic of tectonic evolution and petroleum geology in Lishui Sag, East China Sea Shelf Basin. Natural Gas Geoscience, (03): 397-401.

[12] Lv C, Chen G, Liang J, et al. (2011). Evolutionary history of the Paleogene deposits in Oujiang Sag, East China Sea Shelf Basin. Marine Geology Frontiers, 27 (08): 1-7.

[13] Jiang Z, Ming Y, Yao G. (2019). Study on fault division of Lishui Sag in East China Sea Shelf Basin. Progress in Geophysics, 34 (01): 310-315.

[14] Hao L, Wang Q, Liang J. (2014). Mechanism of hydrocarbon accumulation in Oujiang Sag, the East China Sea Shelf Basin. Natural Gas Geoscience, 25 (06): 848-859.

[15] Dickinson WR. (1985). Interpreting provenance relations from detrital modes of sandstones. Springer, Dordrecht, 333-361.

[16] Bhatia MR. (1983). Plate Tectonics and Geochemical Composition of Sandstones. The Journal of Geology, 91 (6): 611-627.

[17] Roser BP, Korsch RJ. (1986). Determination of Tectonic Setting of Sandstone-Mudstone Suites Using SiO_2 Content and K_2O/Na_2O Ratio. The Journal of Geology, 94 (5): 635-650.

[18] Xia FY, Jiao YQ, Rong H, et al. (2019). Geochemical Characteristics and Geological Implications of Sandstones from the Yaojia Formation in Qianjiadian Uranium Deposit, Southern Songliao Basin. Earth Science, 44 (12): 4235-4251.

[19] Ni JL, Zhang H, Tang XL, et al. (2016). Characteristics of Major Element Geochemistry from Lower Cretaceous Sandstone in Zhucheng Basin and Their Constraint on Tectonic Setting of the Provenance. Journal of Earth Science and Environment, 38 (05): 587-600.

[20] Zhao YL, Liu YJ, Han GQ, et al. (2012). Geochemical Characteristics of Major Elements in the Permian Sandstones from the Central and Southern Great Xing'an Ranges and Discriminations on Their Tectonic Environment of the Provenance. Journal of Jilin University (Earth Science Edition), 42 (S2): 285-297.

[21] Nian XQ, Han FQ, Han JL, et al. (2019). Application of Trace Elements in Discriminating Sedimentary Environment-A Case Study of Strontium-Rich Sedimentary Rocks in The Strontium Ore Area in the Western Qaidam Basin. Journal of Salt Lake Research, 27 (01): 66-72.

[22] Bai J. (2011). Detailed Study of Putaohua Layer in Maoxing Area. China University of Petroleum.

[23] Coleou T, Poupon M, Azbel K. (2003). Unsupervised seismic facies classification: A review and comparison of techniques and implementation. The Leading Edge, 22 (10): 942-953.

[24] Li TT, Wang Z, Ma SZ, et al. (2015). Summary of seismic attributes fusion method. Progress in Geophysics, 30 (01): 378-385.

[25] Zhu SX, Hou MC, Huang ZF. (2019). Reinterpretation of sedimentary facies based on seismic facies of the Buxin Formation in Sanshui Basin, China. Journal of Chengdu University of Technology (Science & Technology Edition), 46 (02): 240-248.

[26] Liu XF, Zheng XD, Xu GC, et al. (2011). Locally linear embedding based seismic attribute extraction and applications. Applied Geophysics, 7 (4): 365-375.

[27] Zhang JL, Sun ZQ, Liu LL, et al. (2019). Sedimentary model of K-Successions Sandstones in H21 Area of Huizhou Depression, Pearl River Mouth Basin, South China Sea. Open Geosciences, 11: 997-1013.

[28] Wang ZJ, Chen HD, Zhang JQ. (2000). Research and prospect of provenance analysis. Sedimentary Geology and Tethyan Geology, 20 (4): 104-110.