Type of Sandstone and Source of Carbonate Cement in the Kongdian Formation (Upper Part), South Slope of the Dongying Depression, East China

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Abstract: The Upper part of the Kongdian formation of the Paleocene-Eocene age consists mainly of fine to medium sandstones. Samples analyzed are from depths of 1572.55 to 2298 m, representing a temperature range of 60.5 to 88.5°C. The petrographic analysis reveals that the reservoir of the Upper part of the Kongdian formation consists mainly of feldspathic and minor amounts of lithic arenite sandstones. The feldspathic sandstone belongs to this formation of composite sources: metamorphic, sedimentary and igneous. The majority of the sources of sandstone of the Upper part of the Kongdian formation came from metamorphic rocks. The carbonate cement of the Upper part of the Kongdian formation contains δ ^{13}C with a range of -6.67 to -21.44 with a mean of -14.06 and δ [18]O with a range of -1.25 to -12.69 with a mean of -6.97. The δ^{13}C may suggest a mixed source from abiotic reaction zone, bacterial oxidation zone, bacterial sulphate reduction zone and from carbonate detrital grain. The majority of the sources of carbon came from the abiotic reaction zone (decarboxylation zone and liquid hydrocarbon generation zone). The δ [18]O values in the carbonate cement of the Upper part of the Kongdian formation reflect a change in temperature and a change in pore waters chemistry.

Key words: Kongdian formation, abiotic reaction, decarboxylation zone, bacterial oxidation, bacterial sulphate reduction

INTRODUCTION

Isotope is derived from Greek (meaning equal phases) and indicates that isotopes occupy the same position in the Period Table. Thus isotopes are defined as atoms whose nuclei contain the same number of protons but different number of neutrons[1]. The carbon has two stable isotopes ^{12}C and [13]C. The heavy carbonate with δ-value more than +20 and light carbonate with δ-value of around -90. There are two methods of preparation and the gas used in all ^{13}C/^{12}C measurements is CO_2. The first methods is the one in which carbonates react with 100% phosphoric acid at temperatures between 25°C and 75°C to liberate CO_2. The second method involves organic compounds generally oxidized at ~1000°C in a stream of oxygen or CuO. The carbon isotopic composition is conventionally given in parts per thousand in δ-notation:

$$\delta^{13}C = \frac{{}^{13}C/{}^{12}C \text{ sample} - {}^{13}C/{}^{12}C \text{ standard}}{{}^{13}C/{}^{12}Cs \text{ tandard}} * 1000$$

For carbonate, it is convenient to use international reference of Cretaceous Belemnite for the Pee Dee formation (PDB). The oxygen isotopic composition is conventionally given in part per thousand in δ-notation:

$$\delta^{18}O = \frac{{}^{18}O/{}^{16}O \text{ sample} - {}^{18}O/{}^{16}O \text{ standard}}{{}^{18}O/{}^{16}Os \text{ tandard}} * 1000$$

Two different scale of oxygen, $\delta^{18}O$ (SMOW) Standard Mean Ocean Water and $\delta^{18}O$ (PDB), the conversion equation of $\delta^{18}O$ (PDB) versus $\delta^{18}O$ (SMOW):

$\delta^{18}O$ SMOW= 1.03086 $\delta^{18}O$ PDB+30.86%
And for CO_2 samples:
$\delta^{18}O$ SMOW= 1.04143 ($\delta^{18}O$ PDB- CO_2)+30.86%
$\delta^{18}O$ SMOW=1.4115 ($\delta^{18}O$ SMOW- CO_2)+30.86%

The analysis of stable isotopes can provide good information on the cementing materials in sedimentary rocks. The carbon and oxygen isotopes are applied to investigate the conditions under which the minerals formed. The stable isotope is used to distinguish between marine and non-marine pore waters. Carbon and Oxygen isotopes reflect changes in pore-fluid composition during burial. The stable isotope is used to identify the source of

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carbon for carbonate cement[2-11]. The primary aim of this study was to characterize the reservoir of the Upper part of the Kongdian formation of the Paleocene-Eocene age in terms of sandstone types, cement types and their sources.

Geological setting: The Bohai Bay Basin belongs to the Eastern region basins (onshore) and sometime known as the Gulf of Bohai Basin. The Bohai Bay Basins is located in Northern China on (115° to122° E longitude and 36° to 42° N latitude) and has an area of 200,000 sq km (Fig. 1). Bohai Bay Basin is characterized by its formation in Tertiary age as part of the Northern China Platform and comprises many depressions (such as Ba Xian, Raoyang, Jin Xian, Qiu Xian, Dongpu, Banqiao, Dongying, etc.). The basin contains rocks of the Archean, Proterozoic, Paleozoic, Mesozoic and Cenozoic periods. The basin was center of major tertiary tectonic activity and controlled primarily by the movement of the Pacific plate. The hydrocarbons present were generated during the time of basin formation and migrate over a short distance. The subsidence of this basin may be fault depressions or down warps. During the Tertiary period the depositional environment in the basin consisted of continental life in fresh to brackish water[12-14]. The Cenozoic Strata in the Bohai Bay Basin are composed of fluvial lacustraine

sediments of dark clastic rocks intercalated with gypsum and halite layers. The Oligocene age was the main evolution period of the Bohai Bay Basin and consists of fluvial lacustraine facies. The Neogene strata are composed of fluvial swamp facies[14]. The Cenozoic strata in the Bohai Bay Basin are divided into: the Kongdian formation of the Paleocene-Eocene age, the Shahejie formation of the Eocene-Oligocene age, the Dongying formation of the Oligocene age, the Guantao formation of the Miocene age and the Minhuazhen formation of the Pliocene age[14-15].

Sedimentology of Kongdian formation: The Kongdian formation is divided into-three parts (Table 1): Lower, Middle and Upper. The Lower part of the Paleocene age is characterized by purple and brown mudstone interbeded with sandstone and conglomerate at the bottom basalt. The Middle part also of the Paleogene age is characterized by fluvial marsh deposits, dark grey and light grey mudstone interbeded with siltstone, carbonate, oil shale, thin coal bed and limestone. The dark mudstone might be the source rock in the basin. The Upper part of the Paleocene-Eocene age is composed of grey, green, brown and white fluvial facies[16]. The fluvial facie is marked by mudstones intercalated with sandstones and siltstones. This study is concerned only with the Upper part of the Kongdian formation of Paleocene-Eocene age.
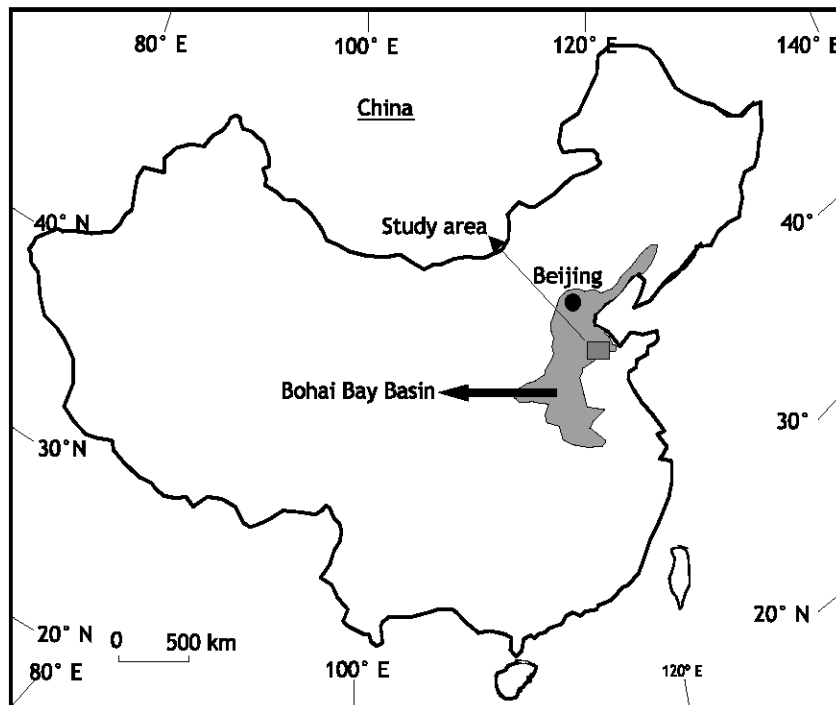

Fig. 1: Location map of the study area

Table 1: Sedimentology of the Kongdian formation[14,15]

Kongdian formation	Eocene	Upper Part	Brown, green, grey and white sandstone interbeded with mudstone. Grey and purple to red siltstone. Grey, green and purple to red mudstone.
	Paleocene	Middle Part	Fluvial marsh deposits, dark grey and light grey mudstone Interbeded with siltstone, carbonate, oil shale, thin coal bed and limestone. The dark mudstone might be the source rock in the basin.
		Lower Part	Consists of purple and brown mudstone interbeded with

Fp= Plagioclase feldspar, Fk = K.feldspar, Qm=Monocrystalline quartz, Qp= Polycrystalline quartz

Table 2: Percentage of the minerals in the Upper part of the Kongdian formation

Well name	Sam. No	Dep. (m)	Fp %	Fk %	Qm %	Qp %	Rock fragment %	Mica %	Calcite cement %	Clay cement %	Pyrite cement %	Heavy mineral %	Porosity
W130	1	2228.00	17	4	51	2	12	-	10	4	-	-	Not good
W130	2	2225.00	25	5	43	2	8	-	12	5	-	-	Not good
W130	4	2224.00	10	2	55	4	6		10	5	8	-	Not good
W130	5	2223.00	23	5	39	1	15	-	10	7	-	-	Moderately good
W130	6	2194.41	15	3	45	1	15	-	8	12	-	1	Not good
W130	7	2191.51	20	3	43	1	7	-	8	17	-	1	Good
W130	8	2190.71	5	20	43	1	15	-	10	6	-	-	Moderately good
W130	14	1964.35	22	2	42	2	15	-	12	5	-	-	Moderately good
W130	23	1753.15	17	2	46	1	13	-	13	7	-	1	Not good
W130	25	1749.60	16	3	58	1	10	-	7	5	-	-	Good
W110	2	2298.00	8	-	50	2	23	-	10	7	-	-	Not good
W110	3	2280.00	5	1	50	4	20	-	-	20	-	-	Not good
W96	1	1920.31	18	3	52	1	10	-	6	10	-	-	Good
W96	3	1938.00	17	7	50	2	8	3	5	8	-	-	Good
W96	5	2155.89	20	2	54	1	8	-	4	10	-	1	Good
W96	6	2192.10	15	7	52	1	8	-	10	6	-	1	Not good
Wx95	1	1847.05	-	-	59	1	20	-		20	-	-	Not good
Wx95	3	1839.95	18	4	50	1	10	1	8	7	-	1	Not good
Wx95	5	1834.20	17	4	45	1	10	2	11	10	-	-	Not good
Wx95	6	1802.42	18	5	46	2	9	2	10	7	-	1	Good
Wx95	9	1572.55	19	3	60	-	7	1	-	10	-	-	Good

MATERIALS AND METHODS

Twenty-one samples have been selected from the Upper part of the Kongdian formation. The samples represent different depths in this formation. Thin sections were prepared and examined under a polarized microscope (Table 2). Ten samples were taken from the carbonate cement of sandstone of the Upper part of the Kongdian formation. The samples represent different depths in this formation. The whole samples were powdered in a tungsten carbide ball mill and were combined with anhydrous phosphoric acid to produce carbon dioxide gas[17]. Table 3 gives the results of isotopic analysis of carbonate cement of the Upper part of the Kongdian formation.

Table 3: $\delta^{13}C$, $\delta^{18}O$ for carbonate cement of the Upper part of the Kongdian formation

Well No.	$\delta^{18}O$ ‰	$\delta^{13}C$ ‰	Depth (m)
Wang 130	-1.25	-6.67	2225.00
Wang 130	-9.03	-12.34	2224.00
Wang 130	-11.75	-11.15	1955.16
Wang 130	-11.18	-19.03	1965.35
Wang 130	-10.21	-17.46	1900.05
Wang 130	-10.57	-14.64	1753.15
Wang 110	-11.25	-21.44	2298.00
Wang 96	-12.69	-6.65	2155.89
Wang 96	-11.47	-12.60	2192.10
Wang 95	-10.96	-9.74	1839.95

Table 4: Percentage of quartz, feldspar and rock fragment in the Upper part of the Kongdian formation

No.	Well name	Sam. No	Depth (m)	Feldspar %	Quartz %	Rock fragment %
1	W130	1	2228.00	24	62	14
2	W130	2	2225.00	36	54	10
3	W130	4	2224.00	15	76	9
4	W130	5	2223.00	33	48	19
5	W130	6	2194.41	23	58	19
6	W130	7	2191.51	31	60	9
7	W130	8	2190.71	28	52	20
8	W130	14	1964.35	29	53	18
9	W130	23	1753.15	24	59	17
10	W130	25	1749.60	22	67	11
11	W110	2	2298.00	10	63	27
12	W110	3	2280.00	8	68	24
13	W96	1	1920.31	25	63	12
14	W96	3	1938.00	25	60	15
15	W96	5	2155.89	26	65	9
16	W96	6	2192.10	27	64	9
17	Wx95	1	1847.05	0	75	25
18	Wx95	3	1839.95	26	61	13
19	Wx95	5	1834.20	27	58	15
20	Wx95	6	1802.42	28	59	13
21	Wx95	9	1572.55	24	67	9

Detrital composition of the sandstones: About 400-600 grains were counted per each slide; and the point counts were recalculated as indicated in Table 4. Over 90% of the samples lie in the field of the feldspathic or sub-feldspathic arenite sandstones (Fig. 2). The feldspathic arenite sandstone of the Kongdian formation

have a feldspar content of more than 25% and little rock fragments in their matrix such as, siltstone, mudstone, chert and volcanic fragments. The sub-feldspathic arenite sandstone contains less feldspar than feldspathic arenite. The feldspar is chiefly plagioclase feldspar rather than K-feldspar.

RESULTS AND DISCUSSION

Classifications of sandstones depend on mineral composition of quartz, feldspar and lithic fragments. Most of the samples lie in the field of feldspathic and sub-feldspathic arenite sandstone and minor amount lie in the field of lithic arenite sandstone (Fig. 2). Among feldspathic sandstones, which is abundant in quartz, feldspar content of more than 25% and lesser amounts of lithic fragment, have long been known by term the *Arkose* which have granitic or granodioritic composition suggesting derivation from coarsely crystalline basement[18]. The composition of the feldspathic sandstone contains less than 25% feldspar, reflecting sub-arkose or sub-feldspathic sandstone. The detrital grains of perthite, microline and orthoclase usually indicate a source area where granitic and high-grade gneisses and schists are exposed. The detrital grains of sandine $(K, Na) Al Si_3 O_8$ indicate alkalic volcanic source, while detrital albite comes chiefly from low-grade metamorphic terrains[18]. The potassic and sodic feldspar are most numerous because they are relatively stable and widespread and abundant in continental source

terrains[18]. Lithic sandstones are those, which contain abundant quartz, more than 25% of lithic grains and lesser amounts of feldspar[18]. Sub-lithic sandstone contains less than 25% of lithic grains[18]. The lithic grains may be indicative of the kinds of source rock terrains from which sand grains were derived, such as small particles of volcanic rock derived from a volcanic source, chert grains derived from a sedimentary source and mica which, may be of a igneous or metamorphic source[18]. The feldspathic arenites, which occur throughout the entire geological column, have obvious provenance significance; a feldspar-rich source area is characterized by predominant K-feldspar consisting of granites, gneisses and other high-rank metamorphic rocks[19]. The feldspathic sandstone (Fig. 3, 4 and 5) in the study area is characterized by: (1) High abundance of quartz, (2) More than 25% feldspar content, (3) Little rock fragments in their matrix such as, siltstone, mudstone, chert and volcanic fragments. The texture of feldspathic sandstone is mainly moderately sorted with rounded grains and angular ones. All the grains are cemented by a matrix usually contains carbonate and silt or clay. The sub-feldspathic arenite sandstone contains less feldspar than feldspathic arenite. The feldspar is chiefly plagioclase feldspar with lesser amounts of K-feldspar. Quartz is characterized by angular to round grains. The lithic arenite sandstones are characterized by: abundance quartz, more than 25% lithic grains and lesser amounts of feldspar[18]. The lithic fragments of sandstones in the study area are characterized by: abundance of rock fragments, especially
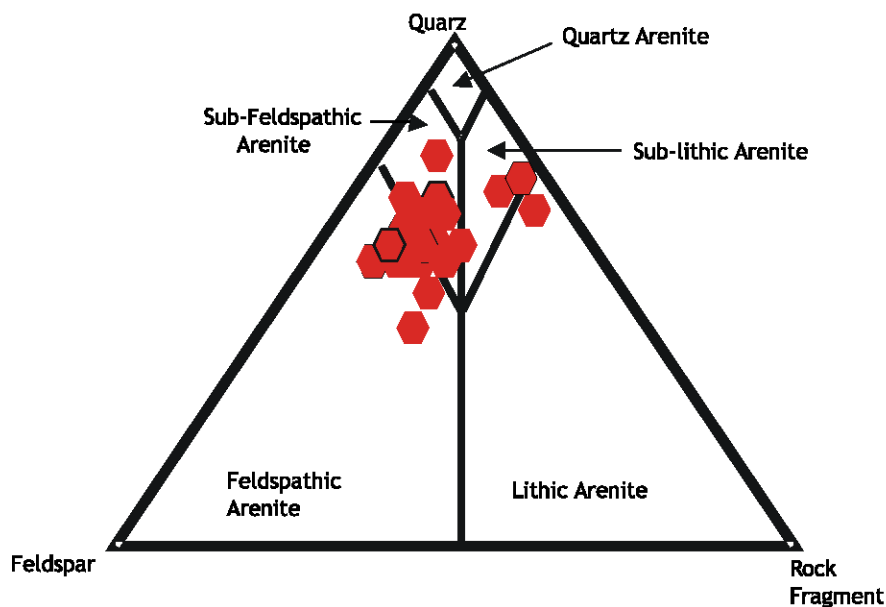

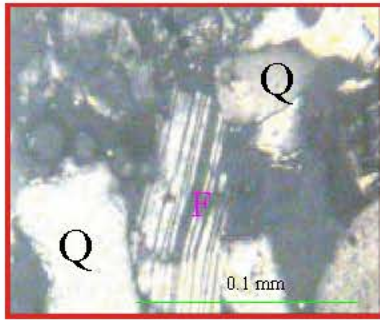Fig. 2: Classification of sandstone of the upper part of the Kongdian formation

Fig. 3: Feldspathic sandstone. The upper part of the Kongdian formation at depth 2280.00 m. (Q) quartz, (F) feldspar
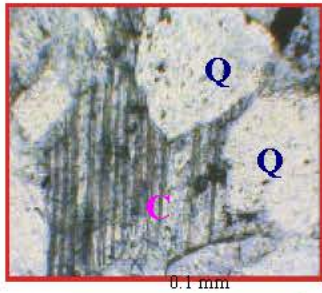

Fig. 4: Piokilotopic calcite cement. The Upper part of the Kongdian formation at depth 2228.00 m. (Q) quartz, © calcite
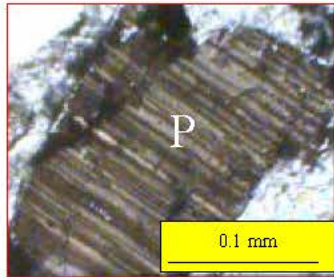

Fig. 5: Plagioclase grain (P), The Upper part of the Kongdian formation at depth 2224 m

that of sedimentary origin and lesser amount of volcanic fragments[16]. The feldspar in feldspathic and lithic sandstones in the study area is composed of sodic and potassic feldspar, suggesting derivation from igneous and metamorphic sources. The lithic fragments in feldspathic and lithic sandstone in the study area consist of chert and volcanic grains, indicating derivation from volcanic, metamorphic and sedimentary source areas. Thus feldspathic and lithic arenite sandstones belonging to the study area indicate the derivations from composite sources: igneous, metamorphic and sedimentary. Most of the sandstone of the Upper part of the Kongdian formation came from a metamorphic source[16].
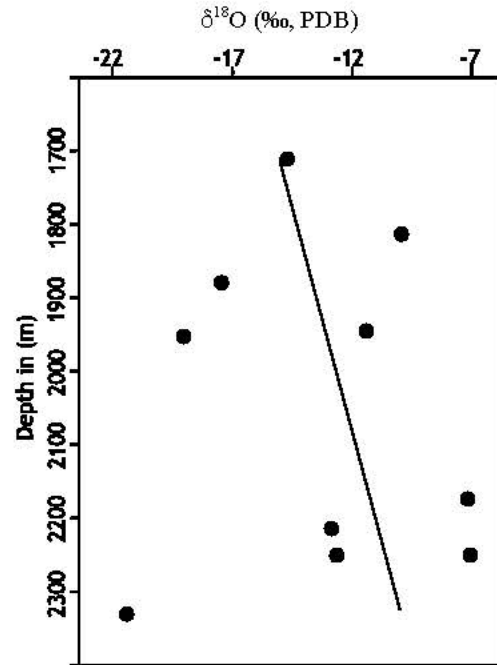

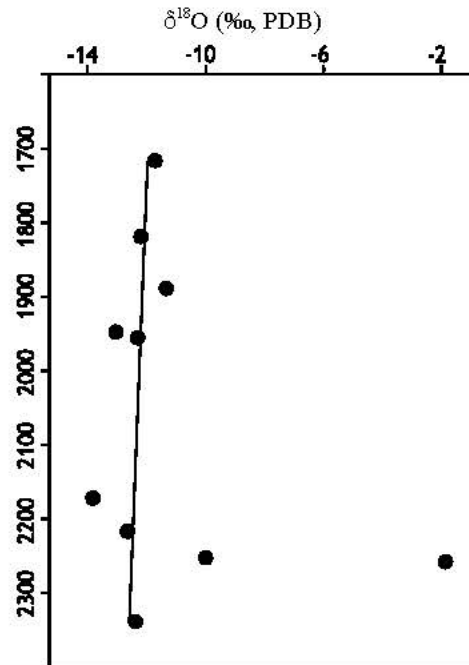Fig. 6: Plot of $\delta^{13}C$ versus depth for carbonate cement of the Upper part of the Kongdian formation

Fig. 7: Plot of $\delta^{18}O$ versus depth for carbonate cement of the Upper part of the Kongdian formation

The carbonate cement of the Upper part of the Kongdian formation contains $\delta^{13}C$ with a range of -6.67 to -21.44 with a mean of -14.06 and $\delta^{18}O$ with a range of -1.25

to -12.69 with a mean of -6.97. Fig. 6 shows that with increasing depth, the positive shift in δ ^{13}C of carbonate cement in the sandstone reflects the positive in δ ^{13}C of the pore water. Macaulay *et al.*[9] noted that the carbon isotopic composition (δ ^{13}C) of diagenetic carbonate minerals reflects the origin of the carbon from which they are composed. In the rift-setting sedimentary basin such as the North Sea, many possibilities exist for sources of carbon from: (1) Marine bicarbonate with δ ^{13}C around 0 ‰. (2) Dissolved inorganic in meteoric water for δ ^{13}C of total dissolved carbon (TDC) range from positive to negative and depend on a combination factors such as (CO_2 from organic carbon contains δ [13]C ~ -25 ‰, carbon from dissolution of carbonate contains δ [13]C ~ +2 ‰ and atmospheric CO_2 contains δ [13]C ~ -7 ‰)[1]. (3) Dissolution shell debris contain δ ^{13}C values close to 0 ‰. (4) From plant and animals remains contain values of δ ^{13}C from -20 to -30 ‰. Irwin *et al.*[3] proposed a general model for sources of carbon. The model suggests that, with increases in depth involved: bacterial oxidation, bacterial sulphate reduction, bacterial fermentation and abiotic reactions produce CO_2 (with δ ^{13}C values of -25 ‰, -25 ‰, +15 ‰ and -10 to -25 ‰, respectively). Also kerogen and petroleum generated from deeper burial contains δ ^{13}C values of -20 to-30 ‰. The biodegradation of petroleum may be the source of CO_2 with δ ^{13}C values +14 to -20 ‰ and magmatic CO_2 with δ ^{13}C values of ~ 7 ‰[1,9]. The association of pyrite with non-ferroan calcite suggests that sulphate reduction was also contributing bicarbonate to cement[8,16]. The majority of carbonate cement of the Upper part of the Kongdian formation in the study area has a carbon isotopic ratio more than -11 ‰ [PDB] and less than -22 ‰ [PDB]. This may suggest a mixed source from abiotic reaction, bacterial oxidation and bacterial sulphate reduction. But the majority of the sources of carbon came from the abiotic reaction zone. Curtis[20] divided the abiotic reaction zone into decarboxylation zone, liquid hydrocarbon generation zone and gas graphite zone. The decarboxylation zone is characterized by: (1) Depth ranges from 1 to 2.5 km and temperature of 30 to75°C, (2) δ ^{13}C values of -20‰, (3) Minerals precipitated including ferroan dolomite, kaolinite, smectite, mixed layer clays and illite. The liquid hydrocarbon generation zone is marked by: (1) Depth of 2.5 to 4.0 km and temperature ranges from 75°C to 120°C, (2) Carbon from primary or early diagenetic carbonates, (3) Minerals precipitated including calcite, dolomite, ferroan dolomite, siderite, kaolinite, smectite, mixed layer clay and illite. The gas graphite zone is characterized by: (1) Depth of more than 4.5 km and temperature more than 120°C, (2) Minerals precipitated including calcite, dolomite, ferroan dolomite, siderite, kaolinite, mica development and chlorite. The less

negative ^{13}C values may indicate the contribution of a heavier carbon released during bacterial fermentation or from the other source. The two most obvious causes for the positive shift with depth in δ ^{13}C values in the pore water are the increasing percentage of detrital carbonate in sand stone and the exclusion of surface water from the closed system of deep sandstone[7]. Figure 4 shows variation with depth in δ [18]O values of sandstone cement of the Upper part of the Kongdian formation and may reflect changes in temperature of precipitation and changes in δ [18]O of the pore waters. According to Dickson[7] the variations with depth in δ [18]O values of sandstone cements may reflect changes in temperature of precipitation and change in δ [18]O values of the pore waters. Figure 7 shows that with increasing in depth, the negative shift of δ [18]O values. The trend of negative shift of δ [18]O values of carbonate cement with increasing in depth might result from increasing of temperatures[7]. Thus the δ ^{13}C values of carbonate cement in the Upper part of the Kongdian formation may suggest derivation of CO_2 from different source: (1) Bacterial oxidation, (2) Bacterial sulphate reduction, (3) Bacterial fermentation, (4) Abiotic reaction zone, (5) From detrital carbonate found in sandstone. But the majority was derived from the abiotic reaction zone (decarboxylation zone and liquid hydrocarbon generation zone). The δ [18]O values in carbonate cement of the Upper part of the Kongdian formation reflect change in temperature and change in pore waters chemistry.

The Upper part of the Kongdian formation of the Paleocene-Eocene age consists mainly of feldspathic sandstones and minor amounts of lithic sandstone. The feldspathic sandstones belong to this formation of composite sources: metamorphic, sedimentary and igneous sources, but mainly from a metamorphic source.

The carbon isotope analysis may suggest that the δ ^{13}C values of carbonate cement in the Upper part of the Kongdian formation derived CO_2 from different sources: bacterial oxidation, bacterial sulphate reduction, bacterial fermentation, abiotic reaction zone and from detrital carbonate found in sandstone. But the majority was derived from the abiotic reaction zone (decarboxylation zone and liquid hydrocarbon generation zone). The δ [18]O values in carbonate cement of the Upper part of the Kongdian formation reflect change in temperature and change in pore waters chemistry.

ACKNOWLEDGMENTS

REFERENCES

1. Hoefs, J., 1987, staple isotope geochemistry. Springer-Verlag, Berlin, Germany, pp: 241.
2. Hudson, J.D., 1977. Stable isotope and limestone lithification. J. Geo. Soc. London, 133: 637-660.
3. Irwin, H., C.D. Curtis and M.L. Coleman, 1977. Isotope evidence for source of diagenetic carbonates formed during burial of organic-rich sediments. Nature, London, 269: 209-213.
4. Land, L.S. and S.P. Dutton, 1978. Cementation of Pennsylvanian deltaic sandstone: isotopic data. J. Sed. Petrol., 48: 1167-1176.
5. Milliken, K.L., L.S. Land and R.G. Loucks, 1981. History of burial diagenesis determined from isotopic geochemistry, Frio Formation, Brazoria Country, Texas. Am. Ass. Petrol. Geol. Bull., 65: 1397-1413.
6. Hamilton, P.J., A.E. Fallic, R.M. Macintyre and S. Ellitt, 1987. Isotopic tracing of the provenance and diagenesis of Lower Brent Group sands, North Sea. In: Brooks, J. and Glenine, K. (Ed) petroleum geology of NW Europe. Graham and Trotman, London, pp: 939-949.
7. Dickson, J.A.D., 1988. Isotopic and petrographic evidence for carbonate diagenesis in non-marine sandstones, Green River basin, Wyoming, J. Sed. Petrol., 58: 227-388.
8. Watson, R.S., N.H. Trewin and A.E. Fallic, 1995. The formation of carbonate cements in the Forth and Balmoral Fields, northern North Sea: a case for biodegradation, carbonate cementation and oil leakage during early burial. Geological society special publication, 94: 177-200.
9. Macaulay, C.I, A.E. Fallic, O.M. McLaughlin, R.S. Haszeldine and M.J. Pearson, 1998. The significance of δ ^{13}C of carbonate cement in reservoir sandstones: A regional perspective from the Jurassic of the northern North Sea. Spec. Publs. Int. Sediment., 26: 395-408.
10. Klein, J.S., P. Mozley, A. Campbell and R. Cole, 1999. Spatial distribution of carbon and oxygen isotopes in laterally extensive carbonate cemented layers: implication for mode of growth and subsurface identification: J. Sediment. Res., 69: 184-201.
11. Taylor, K.G., R.L. Gawthorpe, C.D. Curtis, J.D. Marshall and D.N. Awwiller, 2000. Carbonate cementation in a sequence-stratigraphic framework: Upper Cretaceous sandstones, Book Cliffs, Utah-Colorado: J. Sediment. Res., 70: 360-372.
12. Ma Li, Ge Taisheng, Zhao Xueping, Zie Taijun, Ge Rong and Dang Zhenrong, 1982. Oil basins and subtle traps in the eastern part of China, in the deliberate search for the subtle trap: AAPG Memoir 32: 287-315.
13. Tang Zhi, 1982. Tectonic features of oil and gas basins in eastern part of China: AAPG Bulletin, 66: 509-521.
14. Hu, J., S. Xu, X. Tong and H. Wu, 1989. The Bohai bay basin. In: Zhuxia, Ed. Chinese sedimentary basins., Elsevier, Amsterdam, pp: 89-105.
15. Ni Jinlong, Lu Zhongsheng and Liu Guangdong, 2000. A study of episodic tectonic evolution in China's dongying basin, Petrol. Sci., 3: 31-35.
16. Nafi, M., 2003. Diagenesis of Kongdian Formation (Upper Part), South part of dongying depression, East China: [Dissertation]. China. China Univ. Geosci, China.
17. Mccrea, J.M., 1950. On the isotopic chemistry of carbonates and paleotemperature scale: J. Chem. Phy., 18: 849-857.
18. Williams, H., F.J. Turner and C.M. Gilbert, 1982. Petrography: An introduction to study of rock in thin section. W.H. Freeman and company, San Francisco, pp: 325-358.
19. Carozzi, A.V., 1993. Sedimentary petrography. PTR Prentice, Englewood Cliffs, New Jersey, pp: 17-26.
20. Curtis, C.D., 1978. Possible links between sandstone diagenesis and depth-related geochemical reactions occurring in enclosing mudstones. J. Geol. Soc. London, 135: 107-117.