DOI: 10.3969/j.issn.1006-6535.2013.04.011

高邮凹陷吴堡与句容赤山组沉积特征及地质意义

杨玉平[1]，钟建华[1,2]，段宏亮[3]，张丹峰[4]，邵珠福[1]
（1. 中国石油大学，山东 青岛 266580；2. 中国科学院广州地球化学研究所，广州 510640；
3. 中石化江苏油田分公司，江苏 扬州 225009；4. 中石化石油勘探开发研究院，北京 100083）

摘要：通过露头、岩心，薄片、电镜、测录井等资料的观测和分析，对吴堡低凸起和句容市赤山组进行了地层划分和沉积类型研究。结果表明：赤山组可分为上、下两段，吴堡低凸起下段发育干盐湖、风成沙席、间隙性河流、风成沙丘、丘间，上段发育风成沙丘、丘间、湖三角洲和盐湖沉积，风成砂覆盖范围较大。其中，风成沙丘为典型的沙漠亚相，孔渗性好，可作为重要的烃类储层，而湖三角洲为目前首次在研究区提出，其水下分流河道和沙坝孔渗性好，为良好的油气储层，丘间孔渗性低，可作为储油层或生油层的流体隔层，或为生油层。

关键词：地质意义；地层划分；沉积类型；赤山组；吴堡低凸起；高邮凹陷
中图分类号：TE121.3 **文献标识码：**A **文章编号：**1006-6535(2013)04-0045-05

引 言

苏北盆地白垩系赤山组普遍发育沙漠沉积[1-2]，陈堡油田陈3断块赤山组风成砂岩油藏的发现引起了业界对赤山组沉积环境研究的兴趣[3-6]，但因缺乏对地层的细分和沉积环境的具体研究，导致对赤山组储层砂体分布规律认识不清。因此，急需加强赤山组地层和沉积环境的精细研究，为滚动勘探开发提供有效的指导。

1 地层划分

句容市赤山组露头为1套砖红色砂岩建造，由于后期构造运动的影响，其分布较为分散，厚度变化较大，赤山组可分为上、下两段，下段主要为砖红、紫红色钙质细—粉砂岩、含砾砂岩与钙质黏土岩、黏土岩互层或韵律层出现，上段为棕红、紫红色岩屑石英砂岩、杂砂岩、粉砂岩等，层系底部常含细砾。吴堡低凸起上赤山组分布特征与露头相似，厚度平面分布相差较大，大部分井未钻穿赤山组，一部分井下地层特征与露头相似，另一部分井下地层顶部为灰色、深灰色块状泥岩、粉砂质泥岩夹灰色、深灰色粉—细砂岩薄层，中下部为灰色、深灰色块状细—中砂岩夹灰色、深灰色泥质团块或条带。

基于上述赤山组的特征，结合层序地层学理论分析认为，句容市三岔乡露头和吴堡低凸起井下沙漠相发育的地区以大型的Stokes面（潜水面）为界，将赤山组划分为上、下两段，界面之下岩石均富含钙质，露头中沿此面的局部低凹地段分布着长透镜状，具有水下沉积特征的丘间沉积物。通过岩电特征分析认为，赤山组为一基准面向上变浅再变深的沉积旋回，在湖三角洲及盐湖沉积中通过湖侵作用形成的侵蚀面的识别和基准面旋回特征同样将赤山组分为上、下两段。

2 沙漠沉积类型

前人研究认为，苏北盆地赤山组的形成环境可划分为冲积扇相和沙漠相[7]，吴堡低凸起位于沙漠与湖泊的过渡地带。通过与句容市三岔乡赤山组露头剖面进行对比研究，并结合前人在古沙漠沉积方面的研究成果[8-12]，对吴堡低凸起沉积亚相类型进行了划分。

收稿日期：20121008；改回日期：20121210
基金项目：中国石化股份有限公司项目“吴堡断裂带构造演化及成藏模式研究”（G0716-09-ZS-0039）
作者简介：杨玉平（1981-），女，2005年毕业于中国石油大学（华东）测绘工程专业，现为该校地质学专业在读博士研究生，主要从事构造沉积和石油地质方面的研究。

© 1994-2013 China Academic Journal Electronic Publishing House. All rights reserved. http://www.cnki.net

2.1 干盐湖

井下可见，发育于赤山组底部，岩层被氧化铁浸染，分布不均，大部分集中呈微层状及条带状，使岩石显示显微层状构造，胶结物为硬石膏质和泥质胶结。镜下可见硬石膏呈粗—中晶，灰质呈细晶，白云质呈粉晶，为典型的盐湖蒸发期沉积物特征。

2.2 风成沙席

露头和井下均有发育，岩性主要为粉—细砂岩，露头可见水平面状纹层，下部细层较薄，向上增厚，层间夹薄层泥质粉砂岩、泥岩，沿走向呈不稳定状，厚度为0.5～2.0 m。由于风力强度减弱，湿度相对较大，泥质粉砂岩、泥岩为淹没时的湖缘沉积，暴露时形成干裂泥片，又被薄层砂席沉积物掩盖。电测曲线下部呈指状交互，向上渐变为齿化箱形。

2.3 间歇性河流

露头和井下均可见，分布零散，岩性以粉砂岩、细砂岩为主，含一定量的泥质。根据岩心观察，可见河道底冲刷、生物扰动现象、团块状泥砾、泥质条带及钙质结核，一些砂岩中可见波状层理和小型交错层理，可能为干涸的水道在洪水期充水形成，电测曲线呈钟形。

2.4 风成沙丘

露头和井下均有发育，以砖红、棕红色巨厚至块状细砂岩为主，胶结疏松—中等。砂岩成分以石英为主(60%～70%)，岩屑(11%～27%)、长石(14%～28%)次之，另有少量暗色矿物及重矿物，矿物成熟度和现代一些沙漠相比偏低，这是由于当时气候较干旱的缘故。

粒度概率曲线多呈两段式(图1)，以跃移组分为主，悬浮组分较少，牵引组分缺失，斜度为65～75°，粒度分布集中，分选好，颗粒多为次圆状—圆状，岩石颗粒支撑，接触－孔隙式胶结，泥质杂基及胶结物含量较少，均小于7%，表明砂岩结构成熟度高，存在大量的粒间孔；砂粒表面均包裹着一层铁质薄膜(赤褐铁矿)，俗称“沙漠漆”，为干旱荒漠的重要特征[8]。

镜下石英颗粒表面见贝壳状断口、碟形和V型撞击坑、直撞击沟及霜面，为风扬作用的结果

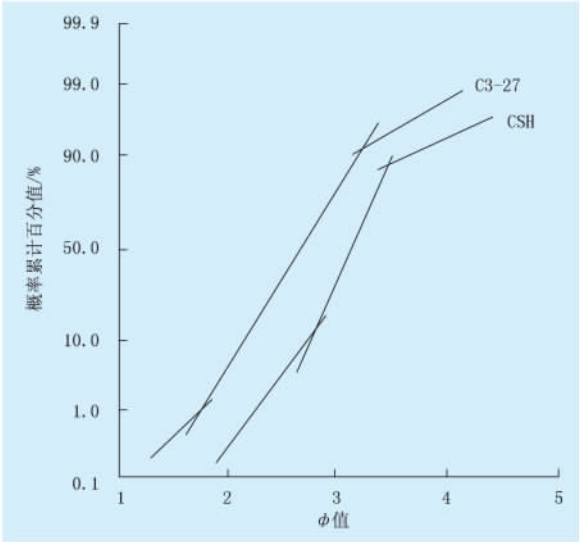
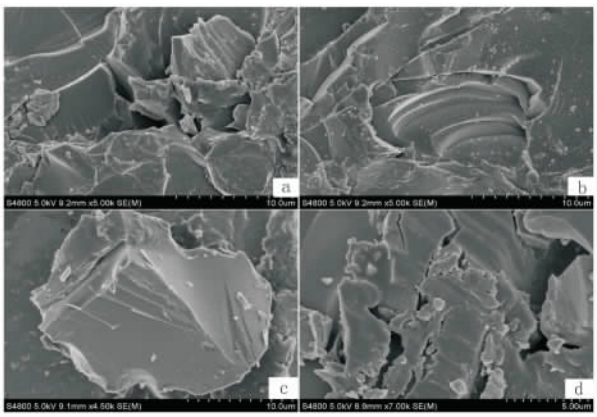


图1 赤山组上段风成沙丘粒度概率曲线

(图2)。句容市赤山剖面可见高角度大型板状交错层理(图3a)，倾角为26～35°，倾向分为80～145°

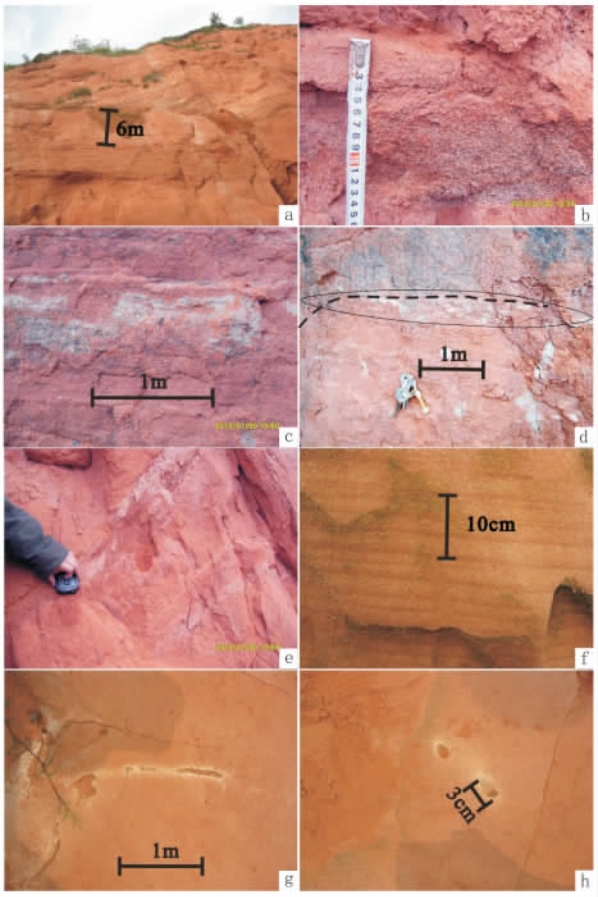


a 贝壳状断口 b 碟形撞击坑及霜面 c V形撞击坑 d 直撞击沟

图2 石英砂颗粒表面特征

和0～40° 2组，推断当时主季风方向为南西向。赤山剖面大型斜层理截切面上见粗砂、细砾石薄层或条带，呈鱼籽状，磨圆度高，具风棱石特征(图3b)；在厚达百米的沉积中发育不同规模的切穿层理的边界面(Stokes面)，即风成砂岩侵蚀下切到地下水位的面，该面上可见灰质斑点和条带，可延伸到丘间泥岩沉积中，丘间该面之上为砂岩沉积，之下为泥岩沉积(图3c～e)，该面为风成砂沉积体系所特有；在沙丘的背风面见条纹码构造，国外学者认为其为碎屑流差异沉积作用所形成[9]，此外可见生物足迹和钻孔，生物钻孔朝着背风面方向，这样可防止风力作用的破坏(图3g、h)。上述为风成砂岩的典型特征，是区别于其他环境沉积物的标志。

© 1994-2013 China Academic Journal Electronic Publishing House. All rights reserved. http://www.cnki.net



a 大型板状交错层理　b 风棱石层　c 灰色灰质斑点及条带形成Stokes面　d Stokes面延伸到丘间泥质沉积中　e 风暴间歇期形成的黏土层　f 背风面形成的条纹码构造　g、h 背风面见虫迹和生物钻孔

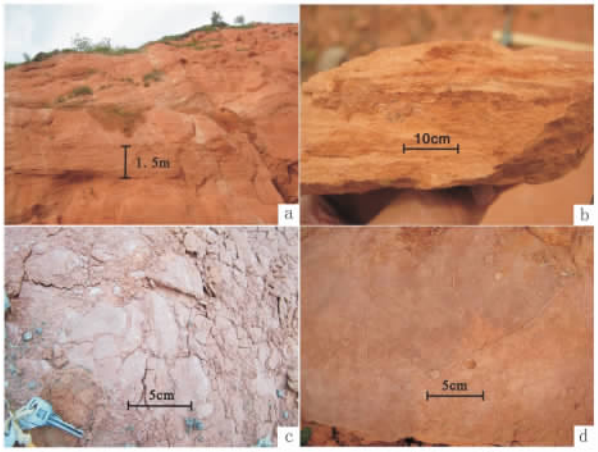
图 3　句容赤山风成沙丘特征

2.5　丘间

丘间沉积可分为湿丘间、干丘间和蒸发丘间 3 种类型，湿丘间在苏北盆地晚白垩系最为发育，为风蚀作用形成的丘间洼地，因潜水面抬升或间歇性降雨而暂时性积水形成，岩性以紫红色泥岩—粉砂岩沉积为主，多呈夹层或透镜状夹于大套粗粒砂岩沉积中。句容市赤山组露头可见沙纹层理、微细水平层理(图 4a、b) ，并发育因强烈蒸发逐渐干涸而形成的泥片、泥裂缝(图 4c) ，而泥裂缝又多被下一次风力携带的风沙灌入填满而形成湿丘间特征性的砂柱、砂脉沉积构造(图 4d) ; 其沉积厚度一般较小(几厘米至十多米) ，分布不稳定，范围局限，垂向上常与沙丘叠置沉积，湿丘间沉积常形成幅度异常的指状测井响应，与沙丘的平直型、低幅度测井响应形成鲜明对照。

2.6　湖三角洲—盐湖沉积

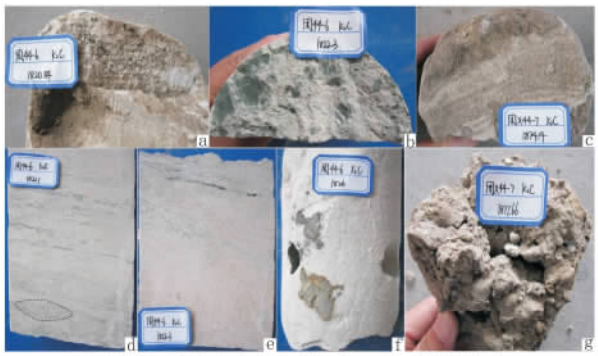
露头和井下皆有发育，岩心以灰色为主，胶结



a 丘间水平层理　b 湿丘间沙纹层理　c 湿丘间收缩泥裂缝及干裂泥片　d 湿丘间泥裂缝被后期风沙充填

图 4　丘间沉积特征

中等—致密。镜下观察石英含量为 50% ~65%，长石为 15% ~25%，岩屑含量为 20% ~30%，黄铁矿呈不规则—凝块状，分布较均匀，体现了沉积环境的还原性，杂基以泥质为主，结构成熟度较低，这是由于物源较近的缘故，岩石颗粒支撑，接触 - 孔隙式胶结，胶结物主要为白云石胶结，局部见铁质胶结，说明湖泊中镁离子含量高，结合前人对苏北盆地赤山组沉积环境研究成果[1-2,4-7]，认为其为盐湖沉积环境，其典型特征有: ①平行层理发育(图 5a) ，层面发育波痕(图 5c) ; ②包卷层理发育普遍(图 5d) ，见粒径高达 3 cm 的灰绿色泥砾(图 5b) ; ③发育正粒序层理(图 5e) ，见黄铁矿结核(图 5f) ，



a 平行层理　b 砂岩中夹灰绿色泥砾　c 层面发育波痕　d 包卷层理　e 正粒序　f 黄铁矿结核　g 泥质砂岩

图 5　扇三角洲水下分流河道和河口坝沉积

上述特征表明该相具重力流水下水道沉积的特征; ④反粒序层理发育，测井曲线呈漏斗形，并呈多期叠加，研究认为是多期沙坝的叠覆沉积; ⑤句容市赤山组露头见地层上超，研究区赤山组沉积时期西部具有一定的坡度，在这样的古地形背景上，结合上述沉积特征认为其与湖三角洲特征相吻合。

© 1994-2013 China Academic Journal Electronic Publishing House. All rights reserved.　http://www.cnki.net

3 沉积相模式

在上述沙漠沉积亚相识别的基础上，结合综合柱状图分析认为(图6)：赤山组下段发育干盐湖、风成沙席、间歇性河道、风成沙丘、丘间沉积，上段发育风成沙丘、丘间、湖三角洲和盐湖沉积。陈堡油田风成沙丘砂层厚达15～50 m，周庄油田厚达百米以上，相对于风成沙丘而言，湖三角洲前缘砂体厚度小、粒度细，泥质含量增加。根据陈堡油田目前已有的资料分析认为，赤山组以风成沙丘沉积为主(图7c)，而位于其西南近7 km的周宋油田，赤山组上、下亚段的平面相分布如图7a、b所示：赤山组下段以风成砂沉积为主，在周36－5井—周38－2新井区发育风成沙丘；赤山组上段风成砂范围后退至周3井、周41－9井区以西，其中，周3井—周41－9井区发育风成沙丘，盐湖、湖三角洲范围较下段向东有所推进。从平面上可见，风成沙丘的分布比较零散，而上述的风成沙丘沉积特征所推断的晚白垩时期的主要季风方向为南西向，合理地解释了周36－5井—周38－2新井区的风成沙丘向周3井—周41－9井区的迁移。

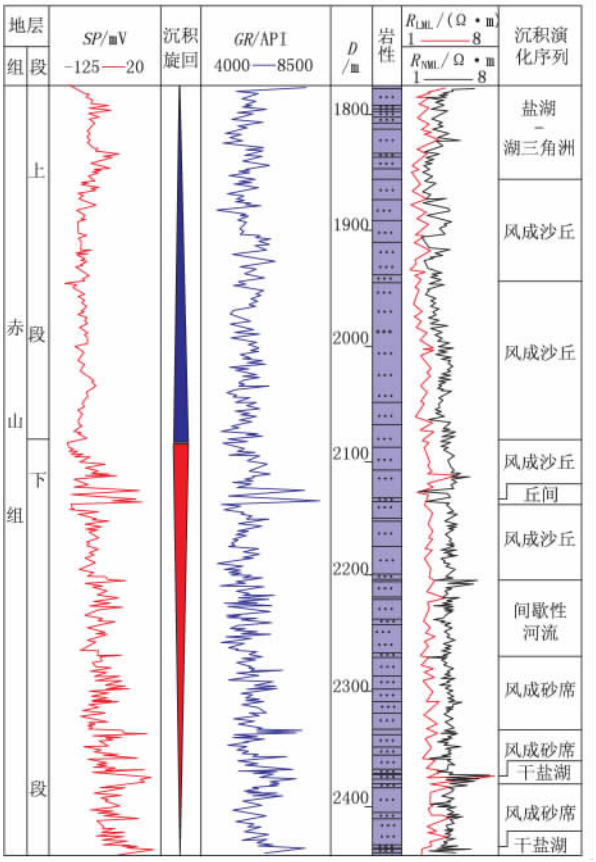


图6 赤山组沉积演化综合柱状图

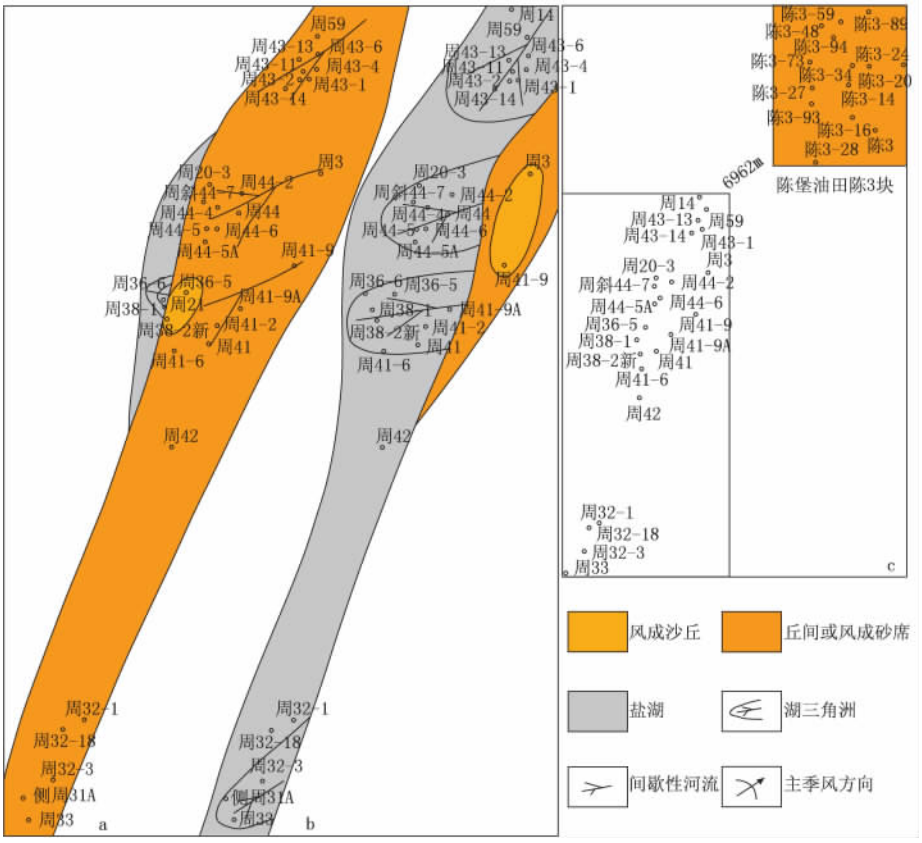


图7 陈堡油田赤山组沉积相平面图

© 1994-2013 China Academic Journal Electronic Publishing House. All rights reserved. http://www.cnki.net

4　油气地质意义

沙丘砂岩一般具有较高的孔隙度,2 km 左右埋深的沙丘砂岩,孔隙度平均达 20% 左右,野外露头则达 25% 左右,是重要的烃类聚集场所; 水下分流河道和沙坝孔隙度平均达 30% 左右,渗透率较高,为良好的油气储层; 丘间亚相细粒沉积物孔渗性较低,可以形成油气藏中储或生油层的流体隔层,在特定的条件下还可以形成生油层。近年来,国内外陆续发现了与古沙漠相关的油气藏,随着勘探和研究的不断深入,沙漠沉积必将成为中国油气储量增长的重要新领域。

5　结　论

(1) 句容市三岔乡露头和吴堡低凸起赤山组可划分为上、下两段,风成砂发育的地区以大型的 Stokes 面为分界面,岩电分析认为赤山组为一基准面向上变浅再变深的沉积旋回,在湖三角洲及盐湖沉积中,以湖侵作用形成的侵蚀面的识别、基准面旋回特征将赤山组分为上下两段。

(2) 句容市三岔乡和吴堡低凸起上沙漠相中识别出了干盐湖、风成沙席、风成沙丘、丘间、间歇性河流沉积、湖三角洲和盐湖 7 种亚相类型。风成沙丘是沙漠沉积中最典型的一类亚相,湖三角洲是目前在研究区首次提出的 1 种沙漠亚相类型。吴堡低凸起赤山组下段主要发育干盐湖、风成沙席、间隙性河流沉积、风成沙丘和丘间亚相; 上段主要发育风成沙丘、丘间、湖三角洲和盐湖沉积。平面上从东向西由风成砂向盐湖相过渡,赤山组下段风成砂覆盖范围较上段大。

(3) 沙丘砂体厚度大,孔渗性较好,是重要的烃类聚集场所。湖三角洲砂体厚度小、粒度细,泥质含量增加,但其水下分流河道和沙坝孔渗性好,为良好的油气储层。丘间亚相孔渗性低,可以形成油气藏中储或生油层的流体隔层,在特定的条件下还可以形成生油层。

参考文献:

[1] 陈清华,庞飞,史鹏. 江苏白垩系古沙漠沉积特征及油气地质意义[J]. 石油天然气学报(江汉石油学院学报),2008,30(5):161 – 164.

[2] 岳文浙,丁保良. 江苏白垩纪陆相层序地层研究[J]. 火山地质与矿产,1999,20(4):287 – 344.

[3] 董顶琴. CB 油田 C3 块赤山组油藏水平井开发可行性研究及应用[J]. 复杂油气藏,2010,3(3): 66 – 68,86.

[4] 罗南. 陈 3 断块泰州组与赤山组接触关系对开发的影响探讨[J]. 小型油气藏,2008,13(2):52 – 56.

[5] 丁圣,林承焰,马宝军,等. 苏北陈堡油田风成砂岩沉积成岩特征及其找油意义[J]. 中国石油大学学报: 自然科学版,2010,34(2):8 – 18.

[6] 陈清华,庞飞,渠冬芳. 苏北盆地白垩系赤山组沉积与储层特征及研究意义[J]. 海洋地质与第四纪地质,2008,28(6):95 – 100.

[7] 岳文浙,业治铮,姜月华. 江苏晚白垩世赤山组沉积环境[J]. 沉积学报,1997,15(S0):1 – 7.

[8] 陈荣林. 苏南上白垩统赤山组风成砂初探[J]. 石油实验地质,1982,4(3):220 – 224.

[9] Juan Pedro Rodriguez – Lopez, Nieves Melendez, Poppe L, et al. Aeolian sand sea development along the mid – Cretaceous western Tethyan margin (Spain): erg sedimentology and palaeoclimate implications[J]. Sedimentology, 2008,55: 1253 – 1292.

[10] Detlef Mader. Depositional mechanisms and facies models of intertongguing aeolian environment and fluvial milieu in the middle buntsandstein in aspects of fluvial sedimentation in the lower triassic buntsandstein of europe. Lecture notes in earth sciences[M]. Verlag Berlin Heidelberg (Springer),1985: 127 – 164.

[11] 李玉文,陈乐尧,江新胜. 川南黔北白垩—第三纪沙漠相及其意义[J]. 岩相古地理,1988,38(6):1 – 14.

[12] 谢渊,王剑,江新胜,等. 鄂尔多斯盆地白垩系沙漠相沉积特征及其水文地质意义[J]. 沉积学报,2005,23(1):73 – 83.

编辑　黄华彪

© 1994-2013 China Academic Journal Electronic Publishing House. All rights reserved.　http://www.cnki.net

fault and dextral tension – torsion of Xinanzhuang fault. This research provides true geological data for petroleum exploration in the Gaoliu fracture belt and is of reference significance to the conformational study of adjacent fracture belts or sags.
Key words: physical simulation; sandbox experiment; extension; Gaoliu fracture belt; Nanpu sag

Sedimentary feature and geologic significance of the formation of Wubao and Jurongchishan of Gaoyou Depression

YANG Yu – ping[1], ZHONG Jian – hua[1,2], DUAN Hong – liang[3], ZHANG Dan – feng[4], SHAO Zhu – fu[1]
(1. *Petroleum University of China, Qingdao, Shandong* 266580, *China*;
2. *Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou* 510640, *China*;
3. *Jiangsu Oilfield Branch of Sinopec, Yangzhou* 225009, *China*;
4. *Exploration and Development Research Institute of Sinopec, Beijing* 100083, *China*)

Abstract: The paper studies the stratigraphic division and sedimentary types of the low heave of Wubao and Chishan Formation by observing and analyzing the data of field outcrop, core, thin section, electron microscope, well logging, master logging, etc. The result shows that Chishan Formation can be divided into two members. In the Lower Member, dry salt lake, aeolian sand sheet, intermittent river, aeolian sand dune and inter – dune, lake delta and falt lake are developed; and in Upper Member, aeolian sand dune and inter – dune, lake delta and salt lake are developed and the aeolian sand dune covers a large area. The aeolian sand dune is a subfacies with typical characteristics of desert sedimentation, whose permeability is good and which can be important hydrocarbon reservoirs. It's the first time for lake delta to be proposed in study up to now, whose distributary channels and sand body under water have good permeability and can be good reservoirs and the region between dunes has low permeability, so the region can be the fluid insulation layers of reservoirs or source beds.
Key words: geologic significance; stratigraphic division; sedimentary types; Chishan Formation; low heave of Wubao; Gaoyou Depression

Control action of the master fracture on hydrocarbon accumulation in south Beier depression

ZHAO Liang
(*Daqing Oilfield Company Limited, PetroChina, Daqing, Heilongjiang* 163712, *China*)

Abstract: This paper studies the characteristics and control action of the master fracture in the process of hydrocarbon accumulation in south Beier depression by analyzing sieve residue log, cores and seismic data. It is believed that the main fracture had segmented the tectonic pattern in faulting period under near NS tensile stress action, generally presenting "two sags, one transition zone and one buried hill drape"; the secondary faults derived from sinistral movement and transpression – inversion action had controlled the formation of structural traps; in late faulting period, the movement of the master fracture weakened; such a pattern had significant impacts on regional sedimentary facies, reservoir conditions and source rock distribution, thus controlled oil and gas distribution in south Beier depression. Exploration targets are proposed for this region in conjunction with oil testing data.
Key words: master fracture; oil and gas distribution; tectonic pattern; reservoir conditions; sedimentary environment; south Beier depression

The influence of fractures on the development of weathering crust reservoirs in the Leikoupo formation in central Sichuan

GAN Xue – qi[1], SONG Wen – yan[2], WANG Zhi – ping[3]
(1. *Schlumberger China Company, Chengdu, Sichuan* 610041, *China*;
2. *Chongqing* 136 *Geological Prospecting Team, Chonqing* 402247, *China*;
3. *CNOOC Tianjin Branch, Tianjin* 300452, *China*)

Abstract: The Leikoupo formation in central Sichuan was denuded during uplifting in Indo – China movement, and formed extensive weathering crust reservoirs in the top Leikoupo formation. However, the reservoirs are low in the degree of prospecting and difficult to explore due to many reasons. The authors have studied fracture characteristics and the distribution of these weathering crust karst reservoirs and analyzed the influence of fractures on the reservoirs by using regional geology, well logging, core data as well as observation of fractures in field geological section. The results of the study indicate that fractures were developed in the study area but in small scale; the development of fractures can be divided into four levels; the development of structural fractures are related with regional tectonic stress field and local structure and local stress field near faults; and the presence of fractures could promote karstification, improve reservoir storage and infiltration capacities, and connect isolated dissolved pores.
Key words: fracture; development and distribution; karstification; reservoir; Leikoupo; central Sichuan

Numerical simulation of subaqueous distributary channel sands

XU Hui[1], LIN Cheng – yan[1], ZHENG Yuan – chao[2], JIA Zhen – zhen[1], DING Sheng[3]
(1. *China University of Petroleum, Qingdao, Shandong* 266580, *China*;
2. *Karamay Vocational and Technical College, Karamay, Xinjiang* 833600, *China*;
3. *Jiangsu Oilfield Company, SINOPEC, Yangzhou, Jiangsu* 225009, *China*)

Abstract: Individual channel sands are compared and identified using analytical hierarchy process based on lithological and electrical characteristics; three types of flow units are recognized through cluster analysis; and a fine geological model has been established with these constraints. Interwell connectivity has been quantitatively discriminated by using production data and system analysis; and a linear program has been established to determine the physical property factor of the grid model so as to reclassify flow units. Different flow units adopt different relative permeability curve, and history matching has been conducted by stages of low, medium and high water cut. The results show that the simulation results highly align with the actual results, and the method can be used for similar reservoirs.
Key words: numerical simulation; individual channel sand; flow unit; relative permeability curve; system analysis; linear program

Key technologies for developing the carbonate buried hill reservoirs in Nanpu depression of Jidong oilfield

LIAO Bao – fang, WANG Qun – hui, YU Zhong – liang, FENG Liang, SUN Yan – chun

© 1994-2013 China Academic Journal Electronic Publishing House. All rights reserved. http://www.cnki.net