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准噶尔盆地中部侏罗系油气藏调整 改造的地质、地球化学响应

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摘要: 准噶尔盆地中部侏罗系油气成藏经历了多源、多期充注和晚期的调整改造。综合运用地质、测井和油藏地球化学等资料, 分析了油气藏经历晚期调整改造后的地质、地球化学响应特征。结果表明: 位于车一莫古隆起北翼的莫西庄、沙窝地地区, 经历反向调整后, 油气藏呈分散和小规模分布、油气藏类型由以构造—岩性油气藏为主变成以地层/岩性油气藏为主, 且油气水层关系复杂; 油层低孔、低渗, 且低含油饱和度、低电阻率, 原油密度和粘度大; 今油水界面高于古油水界面, 部分水层中含有较高的“非烃十沥青质”; 而位于车一莫古隆起北翼的永进地区, 经历同向调整后, 今油柱高于古油柱, 油气藏规模变大。

关键词: 准噶尔盆地; 油气藏调整改造; 油水界面; 石油地质。

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Response of Geology and Geochemistry to Adjustment and Reconstruction of the Jurassic Reservoirs in the Central Part of Junggar Basin

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Abstract: Junggar basin is a large superposed basin in west China that experiences multi-stage tectonics. Preliminary study indicated that Jurassic reservoirs in the central part of Junggar basin experience multi-stage hydrocarbon filling from multiple sources and late adjustment and reconstruction. The geologic and geochemical character of the Jurassic reservoir was investigated by integrating data of geology, drilling and geochemistry. The result indicates that reservoirs after reversing adjustment in Shawodi and Moxizhuang Blocks located in the north limb of Che-Mo paleo-uplift are usually scattered in small scale and their type is usually transforming from structural reservoir into stratigraphic/lithologic hydrocarbon reservoir, and have extremely complex oil-water contact or gas-water contact, low porosity and permeability, low oil saturation and resistivity, but heavier oil density and greater viscosity; the paleo oil-gas-water contact determined by grain-containing-oil inclusion (GOI) analysis lower than the present, there is high content of soluble organic matters (i. e. non-hydrocarbon and asphaltine) in present water layers. However, the reservoir experienced synthetic adjustment in Yongjin Block located in the south limb of Che-Mo paleo-uplift has higher paleo oil-water contact verified by GOI value than the present, and paleo oil column is lower than the present. It means that the reservoir scale is expanding.

Key words: Junggar basin; adjustment and reconstruction of hydrocarbon reservoirs; oil-water contact; petroleum geology.

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0 引言

由于多期构造叠加特别是不同构造时期的差异沉降和构造掀斜作用,多期成藏和多期调整改造是叠合盆地油气地质的基本特征(何登发等,2000,2004;赵文智等,2003;郝芳等,2005;张越迁和张年富,2006;庞雄奇等,2008).地层抬升、断裂活化等引起的油气藏破坏已有相对较多的研究,而对由于晚期构造掀斜、储层产状发生明显变化而导致油气藏的调整改造机理的研究十分薄弱,阻碍了对该类型油气藏油气分布规律的认识.

准噶尔盆地为自古生代以来经历了海西、印支、燕山、喜山运动多期构造旋回的叠合盆地,位于盆地中部的车(车排子)一莫(莫索湾)古隆起主要经历了隆起形成(J_1-J_3)、隐伏埋藏(K-E)、掀斜调整隆起消失(N-Q)3个主要阶段,古隆起的形成与演化控制了盆地中部侏罗系油气藏的形成、喜山期的构造掀斜导致已形成油气藏的调整改造(郝芳等,2005;蔡希源和刘传虎,2005;李伟等,2005;赵宏亮,2006;史建南等,2008;邹华耀等,2008; Zou *et al.*, 2008; 况军等,2009).前人对车—莫古隆起的形成、演化及对油气成藏的控制作用论述较多,而对油气藏调整后的地质、地球化学响应特征较少论及.本研究综合运

用地质、测井和油藏地球化学等资料,主要分析了盆地中部车—莫古隆起北翼莫西庄、沙窝地、征沙村地区(图1)侏罗系油气藏经历反向调整改造后的一系列地质、地球化学响应特征,期望能对该类型油气藏成藏机理的研究有所借鉴.

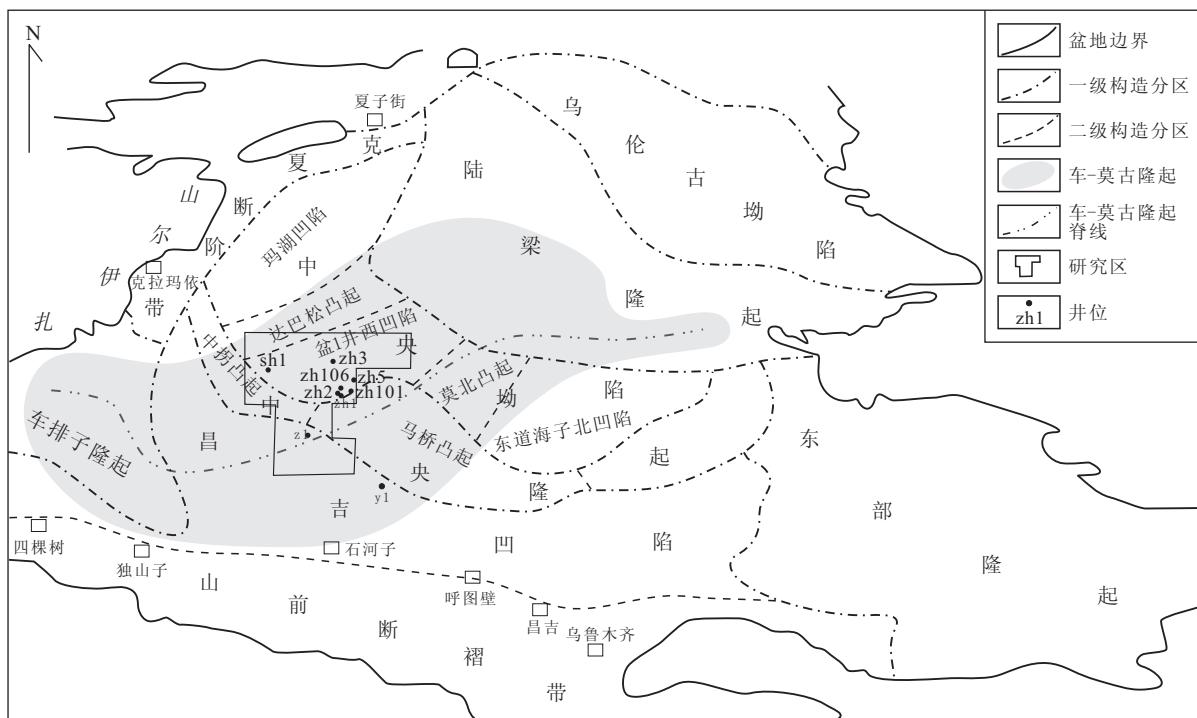
1 油气藏地质特征

1.1 原油物性特征

车—莫古隆起北翼莫西庄、沙窝地、征沙村地区三工河组今储层原油物性分析表明,原油可划分为两大类:第Ⅰ类原油密度大于 0.87 g/cm^3 ,粘度高于 $15 \text{ mPa}\cdot\text{s}$;第Ⅱ类原油密度小于 0.87 g/cm^3 ,粘度低于 $10 \text{ mPa}\cdot\text{s}$.第Ⅰ类原油是油气藏调整后残留的产物,轻质组分在调整过程中优先运移、散失,残留下油质重、粘度较高的原油,如 sh4 井三工河一段储层 $3411\sim3418 \text{ m}$,试油为含油水层,原油密度为 0.8991 g/cm^3 ,粘度高达 $226.89 \text{ mPa}\cdot\text{s}$.而未经历调整或再聚集的油气藏原油密度、粘度均相对较小.

1.2 岩心含油饱和度与储层物性之间对应关系复杂

车—莫古隆起北翼莫西庄、征沙村地区三工河组储层 218 个岩心物性实测数据表明:含油饱和度普遍



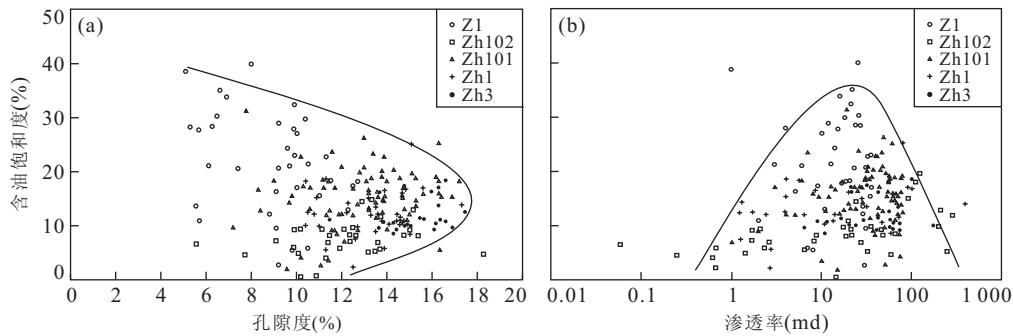


图2 莫西庄、征沙村地区侏罗系油藏岩心含油饱和度与孔隙度(a)和渗透率(b)关系

Fig. 2 Variation of measured oil saturation with porosity (a) and permeability (b) of reservoir rocks in the Moxizhuang and Zhengshachun blocks, Junggar basin

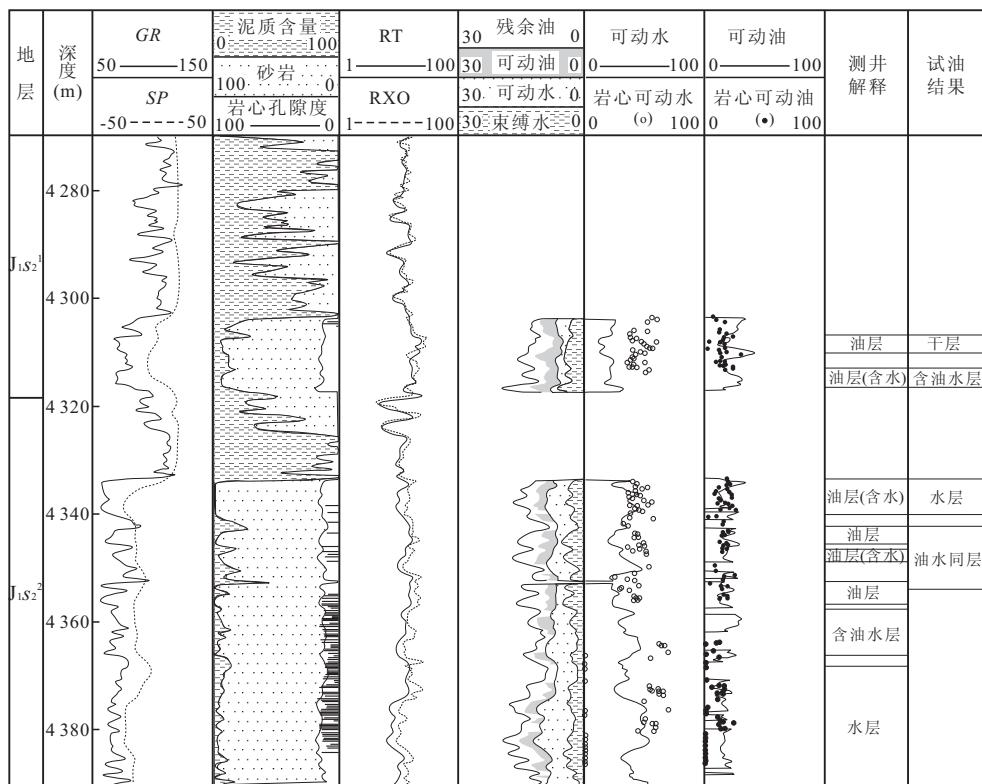


图3 Zh101井测井解释成果

Fig. 3 Results of logging interpretation for well Zh101

较低,主要介于5%~25%之间,且具有随孔隙度增高而降低的特征(图2a);含油饱和度较高的岩心渗透率介于3~100 md,而渗透率较大的岩心含油饱和度较低(图2b).这一现象与常规条件下油气成藏优先充注物性较好的储层相悖,是油气藏调整的重要标志之一,即物性较好、充满度较高的油藏比物性较差、充满度较低的油藏更容易调整散失,其结果是储层物性好的储层含油饱和度低,而相对较差的储层含油饱和度高(郝芳等,2005; Zou *et al.*, 2008).

1.3 油、水界面复杂

车一莫古隆起北翼莫西庄、沙窝地、征沙村地区三工河组油气藏多呈分散和小规模分布,油气藏类型主要表现为地层或岩性油气藏的特征,油气藏没有统一的油气水边界,大多为油水同层,垂向上油、水层间互出现.录井气测值高、岩心见油浸、油斑级别较高的层段,测井解释为油层,但试油结论多为油水同层或含油水层,甚至为水层.部分井试油结论为水层,但其岩心样品检测的含油饱和度仍比较高,具有调整后剩余油的特征.

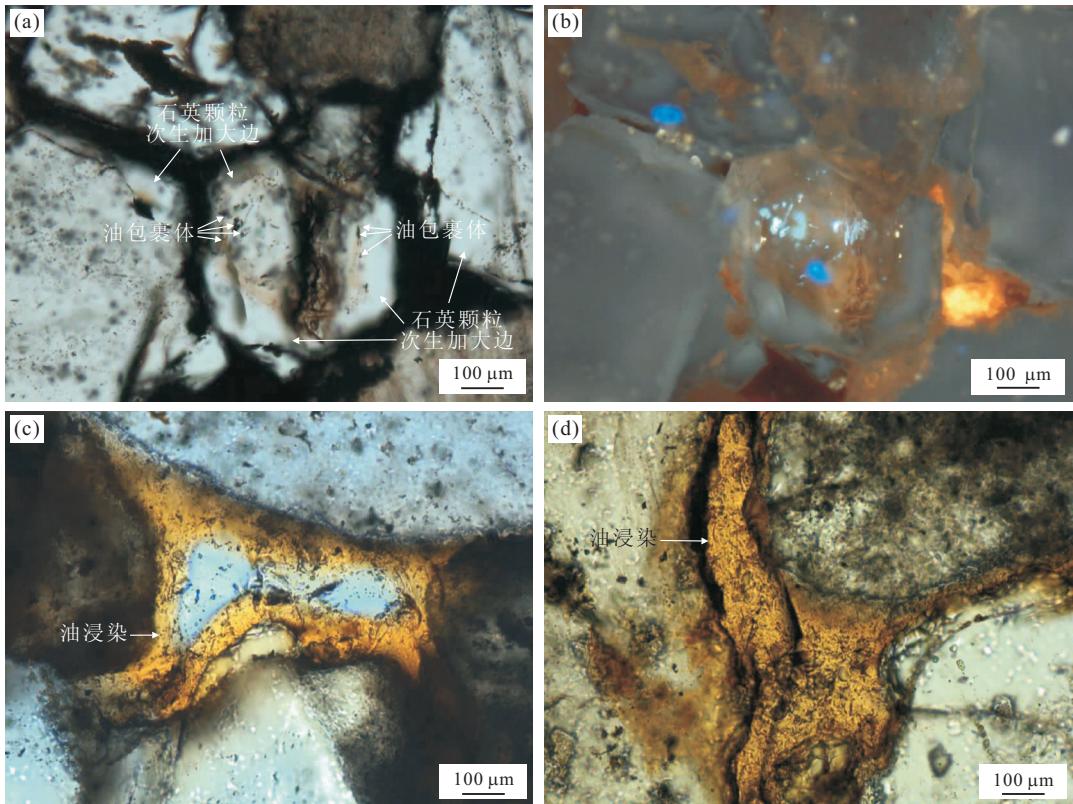


图 4 储层岩石学照片

Fig. 4 Photographs showing the properties of reservoir petrology

a, b. zh3 井, $J_1 s_2^1$, 4 160.50 m, 褐灰色油斑粗砂岩; 石英颗粒内裂纹和石英颗粒次生加大边“粘土迹”中见发蓝白色和黄色荧光油包裹体, 而石英颗粒次生加大边中未见烃类包裹体(a 为透射光, b 为荧光; $\times 100$); c. zh106 井, $J_1 s_2^2$, 4 339.00 m, 黄灰色油浸中砂岩; d. 粒间见大量黄褐色油浸染(透射光, $\times 100$)

2 测井响应特征

准噶尔盆地中部莫西庄、沙窝地地区三工河组为低孔、低渗、低电阻油气藏, 储层物性非均质性强, 且具有低含油饱和度、高束缚水、储层强亲水的特征; 油水关系复杂, 油气显示的井段长; 油气层、水层的电性在纵向上差异小, 横向上变化大。一般用于指示含油饱和度高低的电阻率曲线在各井随深度变化规律并不明显, 油、水层间互分布, 不符合一般油气藏的上油下水的分布规律; 油、水层电阻率接近, 电阻率增大率小于 3, 呈现明显的低阻特征; 测井解释油层含油饱和度偏低, 在 21.6%~73.0% 之间, 油水层判别标准不一; 录井、测井解释结果与试油结果矛盾大, 测井解释为油层试油结果多为油水同层或水层(图 3)。

3 储层岩石学特征

地层水与岩石矿物的相互作用是储层成岩作用

的主要方式, 也是储层胶结物或自生矿物形成的主要途径。孔隙流体的流动对成岩过程起关键作用(Lynch, 1996)。油气在进入储层后会导致储层发生一系列有机质参与下的有机—无机成岩作用, 从而留下油气运移的储层岩石学记录, 如: 自生矿物及流体包裹体的形成。

国内外的研究表明(Saigal *et al.*, 1992; Nedkvitne *et al.*, 1993; Marchand *et al.*, 2000, 2001, 2002; 蔡春芳等, 2001): 油气侵入储层后, 石英次生加大仍继续, 但明显受到抑制, 自生伊利石的形成、钾长石的钠长石化等则被中止; 从油气层到水层, 次生石英数量明显增加。因此, 通过研究储层中成岩矿物和其中的流体包裹体的特征可以推测油气聚集史, 识别古油层的分布与演化。

莫西庄、沙窝地地区储层砂岩中发育的成岩矿物按先后顺序依次为早期胶结方解石, 早期石英颗粒次生加大、晚期亮晶方解石和晚期石英颗粒次生加大。石英次生加大和亮晶方解石胶结现象较为普遍, 但不同井不同地段有所差别。油层、油水过渡带

表1 不同级别油、水层中储层岩心样品抽提物族组分平均值
Table 1 Average of extracts from core samples of different level oil-bearing rocks

含油性	样品数	饱和烃(%)	芳烃(%)	非烃(%)	沥青质(%)	非烃+沥青质(%)	氯仿沥青“A”(mg/g)
干层	18	66.92	12.07	11.58	7.45	19.26	2.97
油层	23	60.60	14.66	13.20	9.14	22.34	8.40
含水油层	15	56.34	17.98	15.62	8.70	24.32	6.27
油水同层	38	64.18	16.31	13.14	6.05	19.16	4.75
含油水层	8	60.32	16.60	14.36	8.48	22.83	7.24
水层	70	43.53	14.13	17.00	24.70	41.69	2.88

和水层中均可见石英颗粒次生加大,但油层、油水过渡带石英次生加大现象不如水层普遍,水层砂岩样品中可见一定数量的油气包裹体分布于石英颗粒次生加大之前的成岩愈合裂隙中或早期石英次生加大边及其边缘,而晚期次生加大边中未见油气包裹体(图4a, 4b),说明现今的水层在早期石英颗粒次生加大之前曾经是古油层,后期油气散失,水体补充进入孔隙,在一定的介质条件下发育石英颗粒次生加大边或晚期胶结方解石,但次生加大边和晚期胶结方解石中不再发育油气包裹体。

另外,有一些物性较好的含油井段,油气包裹体少见,但岩石粒间孔隙中见大量发亮黄色荧光油浸染,透射光下呈黄褐色(图4c, 4d),试油结论多为油层或油水同层,可能为晚期油气藏调整油气再运移聚集形成。

4 油气藏地球化学特征

4.1 砂岩储层中可溶有机质分布特征

对莫西庄、沙窝地及征沙村地区172个岩心样品(试油结论分别为油层、含水油层、油水同层、干层、含油水层和水层)抽提物的统计结果表明:油层、含水油层、油水同层和含油水层中岩心抽提物中“非烃+沥青质”含量一般小于30%,氯仿沥青“A”含量大于2 mg/g,饱和烃含量大于50%;水层岩心样品中氯仿沥青“A”的含量一般小于2 mg/g,可溶有机质中“非烃+沥青质”的含量普遍较高(大于30%)(表1,图5)。李伟等(2005)对本区岩石热解参数的研究也表明:油层中总烃和轻质组分含量相对较高,“非烃+沥青质”和残油含量较低;水层中总烃和轻质组分含量相对较低,而“非烃+沥青质”和残油含量相对较高。分析认为:现今部分水层原先可能存在原油聚集,后期由于储层产状发生变化油气发生运移散失,原油中易于运移的烃类等轻质组分被运移走,留下重质组分或极性较强的组分(如非烃、沥青

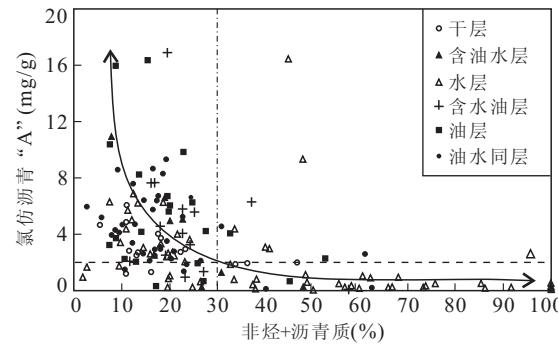


图5 三工河组油、水层中储层岩心氯仿沥青“A”与“非烃+沥青质”含量关系

Fig. 5 Relationship of content between chloroform bitumen A and soluble organic matters (i.e. non-hydrocarbon and asphaltine) extracting from core samples of different level oil-bearing rocks of Sangonghe Formation

质等),从而造成储层中残留油中非烃和沥青质的含量相对较高;现今的含油水层、油水同层和含水油层部分可能为古油气藏部分散失而形成。

从图5和表1中还可以看出,油层、含水油层、油水同层和含油水层中这几项参数差别不甚明显,进一步说明了研究区油、气、水层的复杂性。

根据油藏地球化学实验数据,结合岩心录井、气测录井、测井解释和试油成果,大致划分了研究区部分井现今的油、水界面,如推测Zh101井现今油水界面在4 355 m左右(图6)。

4.2 含油包裹体颗粒指数(GOI)识别古油气层

利用含油包裹体颗粒指数(GOI值)识别古油层是目前常用的技术(Eadington *et al.*, 1996; Lisk *et al.*, 2002; Brincat *et al.*, 2006; 姜振学等, 2006; 孙玉梅, 2006; 王飞宇等, 2006; Cao *et al.*, 2007)。基于大量已知油田的实际资料,Eadington *et al.*(1996)认为GOI<1.0%时,储集层为水层或含油水层;GOI>5%为油层,运移通道的GOI值多为1%~5%。油层与水层GOI数据存在明显的数量级差别,由此可以确定古油水界面及古油柱的高度。

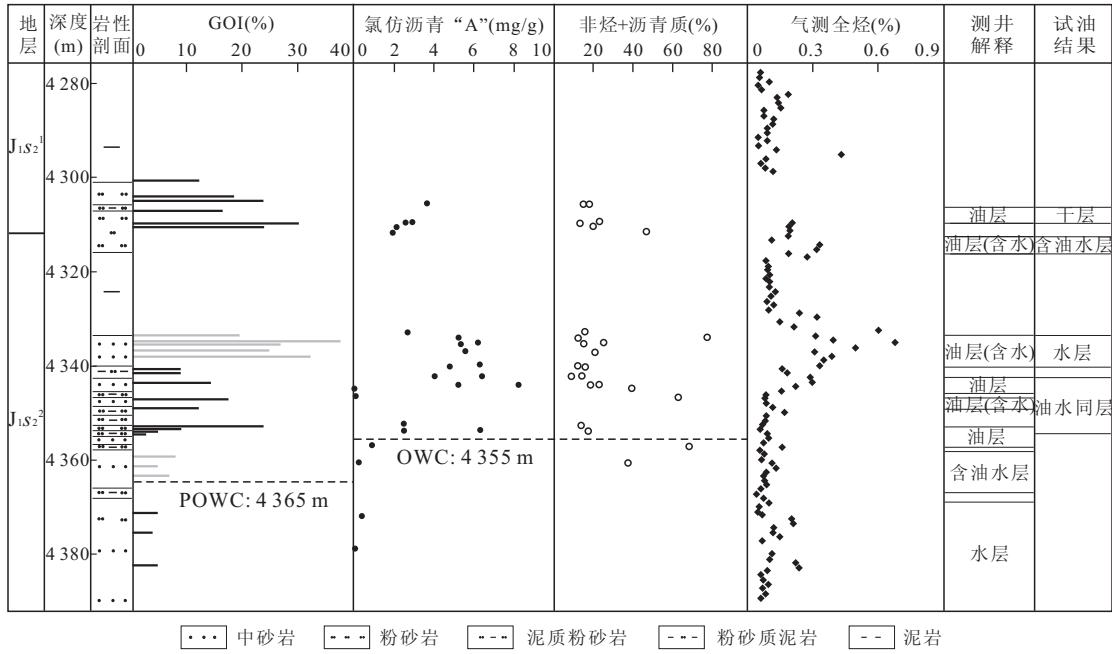


图6 Zh101井三工河组油层古、今油水界面划分

Fig. 6 Partitions of paleo and present oil-water contact in Sangonghe Formation for well Zh101

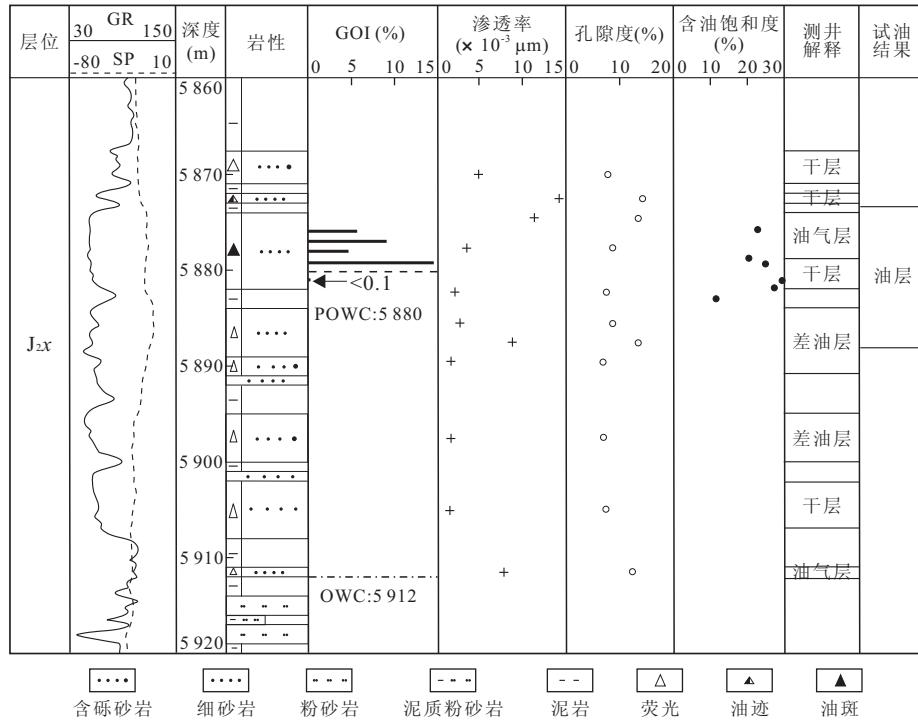


图7 Y1井西山窑组油层古、今油水界面识别

Fig. 7 Partitions of paleo and present oil-water contact in Xishanyao Formation for well Y1

GOI分析结果表明,车一莫古隆起北翼莫西庄、沙窝地地区古油气水界面低于现今油气水界面,古油柱高于现今油柱(图6),利用GOI值确定的Zh101井古油水界面分布为4365 m,低于现今油水界面;该油藏的一些水层与油层和含水油层具有同

样的含油包裹体颗粒指数(GOI值均高于5%),可能表明现今的水层曾发生原油聚集,经历后期的反向调整,油气散失;现今的含油水层、含水油层和油层等可能为调整后残余油气藏或再聚集型油气藏。而位于车一莫古隆起南翼的永进油田,含油包裹

体颗粒指数 GOI 值确定的 Y1 井古油水界面高于现今油气水界面,古油水界面高于今油水界面(图 7),油气藏同向调整使得油气藏规模逐渐变大。

5 结论

(1) 准噶尔盆地中部车一莫古隆起北翼的莫西庄、沙窝地地区的侏罗系油气藏经历反向调整后,主要呈分散和小规模分布,油气藏类型主要表现为地层或岩性油气藏的特征;储层岩心含油饱和度普遍较低且油质重、粘度高,油水界面复杂,各测井参数难以有效识别油气水层,录井、测井解释结果与试油结论矛盾大。

(2) 莫西庄、沙窝地地区侏罗系三工河组油气藏中,部分含油级别较低的储层或水层中岩心抽提物含量相对较高,且水层中“非烃+沥青质”的含量普遍较高;GOI 指数确定的古油气水界面低于现今油气水界面,古油柱高于现今油柱,现今油气藏多为残留、散失型油气藏,少数可能为晚期再聚集型油气藏;而位于车一莫古隆起南翼的永进油田侏罗系西山窑组油气藏,古油水界面高于今油气水界面,今油气藏规模大于古油气藏,是有利的勘探领域。

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