Diagenesis of Unconformity Semi-Weathered Rock Layer and Its Influence on Reservoir Physical Property: A Case of Unconformity on the Top of Triassic in Xia 9 Wellblock, Junggar Basin, NW China*

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Abstract

The unconformity semi-weathered rock layer on the top of the Triassic in the northwestern margin of Junggar Basin is one of the most important hydrocarbon-producing layers in the Xia 9 wellblock. The influence of diagenesis on the reservoir physical property of the unconformity is obvious and serious. Based on the systematic observation of cores, normal sections, cast sections, and scanning electronic microscope, the diagenetic characteristics of the unconformity semi-weathered rock layer and its influence on the reservoir physical property were analyzed in order to expand the understanding of the unconformity and guide fine exploration and development of stratigraphic hydrocarbon reservoirs. The semi-weathered rock layer had undergone a series of diagenesis, such as compaction, cementation, dissolution, and disruption in burial diagenetic evolution. Among them, compaction and cementation were the main factors for destroying pores of the reservoir, while dissolution and disruption were constructive for pores of the reservoir. The semi-weathered rock layer has mainly remained in the stage A of middle diagenesis. The degree of alteration has become gradually weak with the increase of distance from the unconformity surface. The quantitative evaluation of diagenesis shows that the semi-weathered rock layer has diagenetic characteristics as follows: strong compaction (average optic compaction 67.28%), middle cementation (average optic cementation rate is 42.97%), and strong dissolution (average optic dissolution porosity is 65.00%). The relative strength of diagenesis is arranged according to their influence on reservoir physical property in the following order: compaction > dissolution > cementation > disruption. Therefore, dissolution is the main factor controlling good reservoir properties of the unconformity semi-weathered rock layer on top of the Triassic.

Introduction

The research of unconformity diagenesis is still insufficient due to the unique formation mechanism and complex diagenetic process, quantitative research has increasingly become the goal of unconformity evaluation (Rodrigo and Luiz, 2002; Wu et al., 2003; Ali et al., 2010). The unconformity semi-weathered rock layer on the top of the Triassic in the northwestern margin of the Junggar Basin is one of the most important hydrocarbon-producing layers in Xia 9 wellblock (Figure 1). The influence of diagenesis on the unconformity reservoir physical property is obvious and serious, which has been the key constraint to exploration and development of stratigraphic reservoirs. Based on systematic observation of cores, normal sections, cast sections, and scanning electronic microscope, diagenetic characteristics of the unconformity semi-weathered rock layer were analyzed and their influence on physical properties are discussed in order to expand the understanding of unconformity.

Diagenetic Characteristics

The unconformity semi-weathered rock layer on the top of the Triassic in Xia 9 wellblock is 407.50 m thick with a buried depth from 1,427.50 m to 1,835.00 m. It is shown in microscopic images that the diagenetic phenomena is widespread in semi-weathered rock layers due to a series of diagenetic evolution (Figure 2). The main diagenesis types in the semi-weathered rock layer of the study area include compaction, cementation, dissolution, and disruption. Compaction is strong, the grain contact relationship is almost all linear. Dissolution is widespread and strong, developed pore types mainly include intergranular dissolved pores and intragranular dissolved pores which occupied a bigger proportion of the pore space. Cementation is mainly carbonated cementation (especially siderite cementation) and clay mineral cementation followed by siliceous cementation. Disruption formed a number of microfractures. Among them, compaction and cementation were the main factors for destroying pores of the reservoir, while dissolution and disruption were constructive for pores of the reservoir.

The main diagenetic evolutionary sequence of the semi-weathered rock layer is as follows: particle argillation, compaction→chloritization, illitization→calcilization→kaolinisation→dissolution→quartz overgrowth→sideritization→dissolution→iron clay montmorillonite filling. The diagenetic evolution stage is divided into stage A and stage B of early diagenesis and A substage of middle diagenesis. The reservoir is experiencing A substage of middle diagenesis as a whole (Figure 3). The rock alteration is widespread and regular, which is characterized by the degree of alteration weakening with the distance to unconformity surface increased.

Diagenesis Evaluation

After combing through sample data of 14 cores from three wells in Xia 9 wellblock (Table 1), apparent compaction percentage, apparent cementation rate, and apparent relative dissolution porosity of the unconformity semi-weathered rock layer were determined. Their average values were 67.28%, 42.97%, and 65.00% respectively (Table 2), were calculated quantitatively, combined with statistics of particle features of rocks, pore composition, and matrix composition. As can be seen, compaction, cementation, and dissolution have a significant influence on the reservoir physical property of the unconformity reservoir, which indicates the complexity of diagenesis.

Effect of Diagenesis on Reservoir Physical Property

Compaction of the semi-weathered rock layer increases linearly with buried depth; meanwhile, porosity decreases linearly as compaction enhances (Figure 4). Compaction has induced the decrease in unconformity reservoir porosity (26.1%), which indicates that compaction plays an important role in unconformity physical property.

The evaluation results show that porosity decreases as the degree of cementation increases (Figure 5 left). Cementation has resulted in the loss of reservoir porosity (4.3%).

Porosity of the semi-weathered rock layer increases as the dissolution enhances (Figure 5 right), and the content of dissolution pores of different wells at different depth is relatively high (Figure 6), which indicates that dissolution is the major diagenesis for increase of the pore space and improvement of reservoir porosity (6.0%).

Most microfractures suffered weathering-leaching alteration to form dissolution microfractures, which greatly increases the flow capacity of the semi-weathered rock layer (Figure 2k, Figure 2l).

Compaction and cementation are the main diagenesis types of reducing reservoir porosity (Purvis, 1995; Miller et al., 2012). Their relative strength to porosity can be evaluated through porosity reduction by compaction and cementation. As shown in Figure 7, all the sample points fall at the bottom left of the diagonal line, indicating porosity reduction by compaction exceeds that of cementation. Compaction is the chief diagenesis that results in poor reservoir physical properties.

As to cementation and dissolution, cementation is measured by the content of cement and dissolution is measured by apparent dissolution of surface porosity. Relative intensity of cementation and dissolution is characterized by the content of cement / apparent dissolution surface porosity ratio. As shown in Figure 8, dissolution has a greater influence on the formation of reservoir pores in the semi-weathered rock layer.

Conclusions

The unconformity semi-weathered rock layer on the top of the Triassic in Xia 9 wellblock had undergone a series of diagenesis during its formation process, as compaction, cementation, dissolution, etc. The unconformity reservoir has mainly remained in the stage A of middle diagenesis, the degree of alteration has become gradually weak with the increase of distance from the unconformity surface. The quantitative evaluation of diagenesis shows that the semi-weathered rock layer has diagenetic characteristics as follows: strong compaction (average apparent compaction percentage is 67.28%), middle cementation (average apparent cementation rate is 42.97%), and strong dissolution (average apparent relative dissolution porosity is 65.00%). The relative strength of diagenesis is arranged according to their influence on reservoir physical property in the following order: compaction > dissolution > cementation > disruption. Compaction, cementation, and dissolution can cause -26.1%, -4.3%, and 6.0% of porosity fluctuations respectively, and dissolution is important constructive diagenesis.

Acknowledgements

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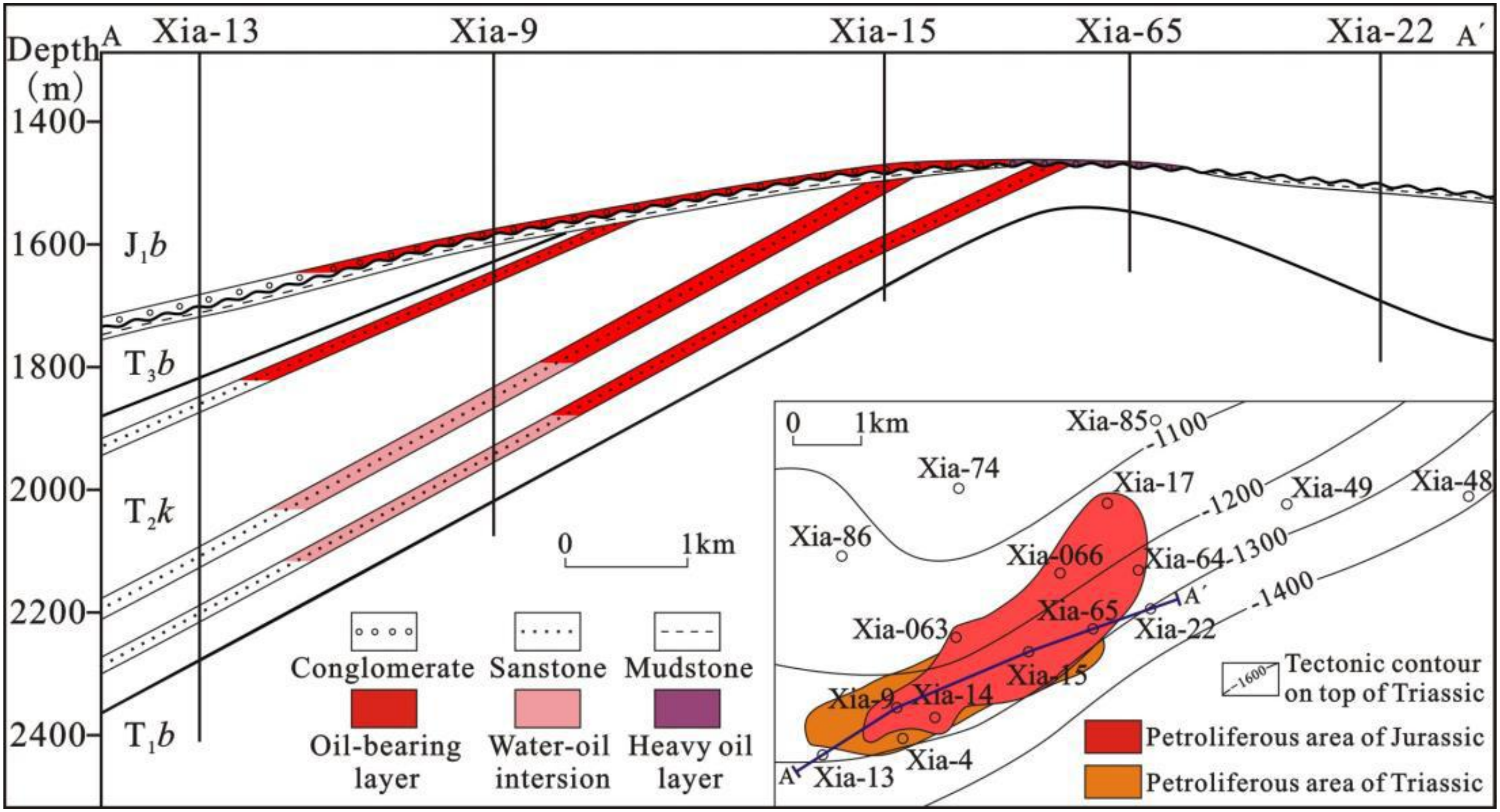

Figure1. Reservoir profile of Xia 9 wellblock in northwestern margin of Junggar Basin.

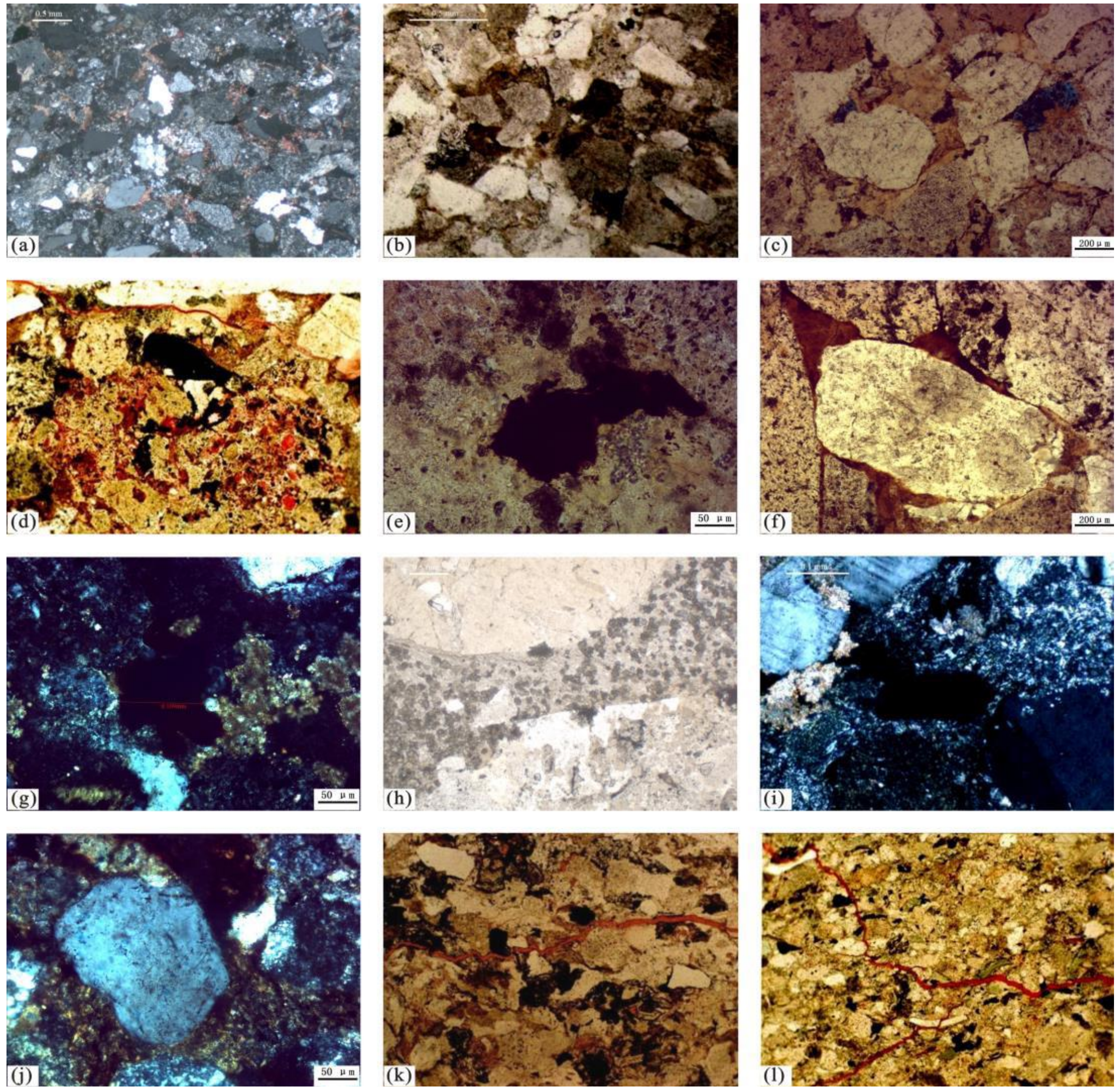

Figure 2. (a) Well Xia 48, 1,529.00 m, particle line contact, quadrature light. (b) Well Xia 48, 1,538.50 m, particle line contact, plainlight. (c) Well Xia 64, 1,480.15 m, intragranular dissolved pore, plainlight. (d) Well Xia 65, 1,483.00 m, intergranular dissolved pore, 5×10. (e) Well Xia 64, 1,480.15 m, iron clay montmorillonite fill dissolved pore, plainlight. (f) Well Xia 65, 1,483.00 m, residual iron clay montmorillonite fill intergranular pore, plainlight. (g) Well Xia 64, 1,480.15 m, siderite cementation, quadrature light. (h) Well Xia 15, 1,539.44 m, siderite in the form of pelletoid, plain light. (i) Well Xia 48, 1,529 m, argillaceous and calcite cementation, quadrature light. (j) Well Xia 64, 1,479.15 m, quartz overgrowth, quadrature light. (k) Well Xia 64, 1,478.65 m, microfracture, 8×10, cast; (l) Well Xia 65, 1,560.13 m, microfracture, 6.3×10, cast.

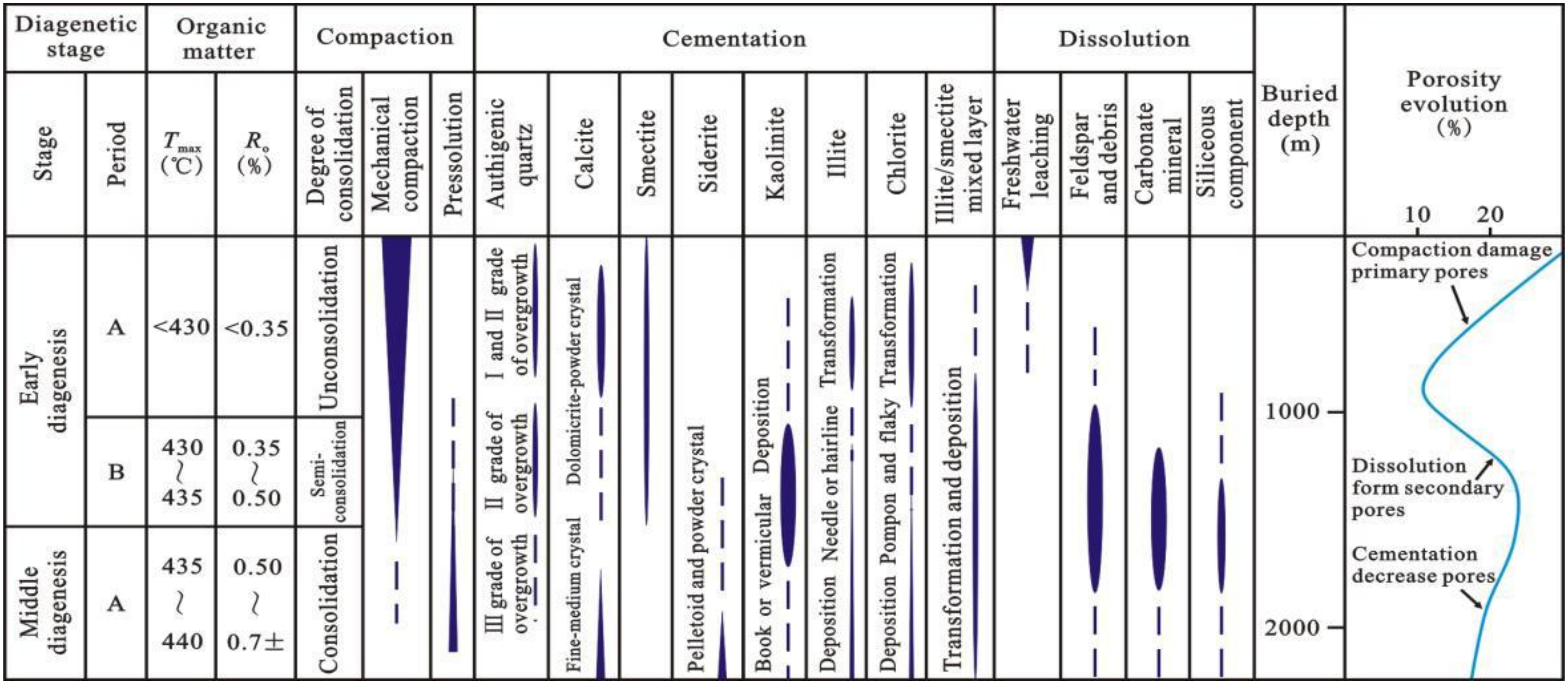

Figure 3. Division of diagenetic stages of unconformity semi-weathered rock layer.

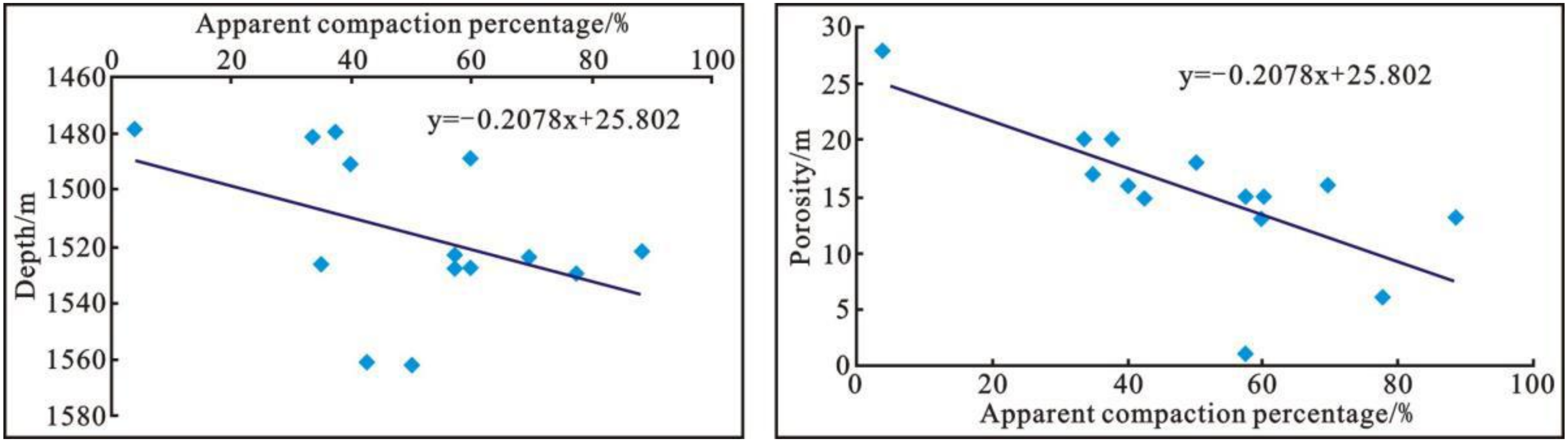

Figure 4. Diagram of compaction and depth and porosity of unconformity semi-weathered rock layer.

The evaluation results show that porosity decreases as the degree of cementation increases (Figure 5 left). Cementation has resulted in the loss of reservoir porosity (4.3%).

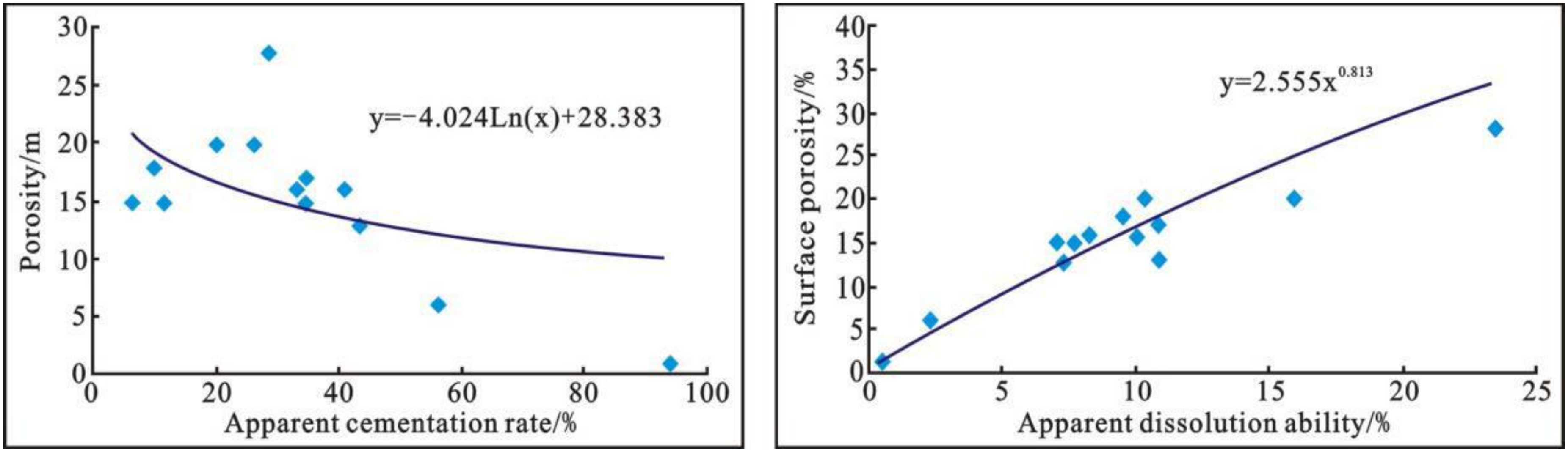

Figure 5. Relationship between cementation (left), dissolution (right), and porosity of the unconformity semi-weathered rock layer.

Porosity of the semi-weathered rock layer increases as the dissolution enhances (Figure 5 right), and the content of dissolution pores of different wells at different depth is relatively high (Figure 6), which indicates that dissolution is the major diagenesis for the increase of the pore space and improvement of reservoir porosity (6.0%).

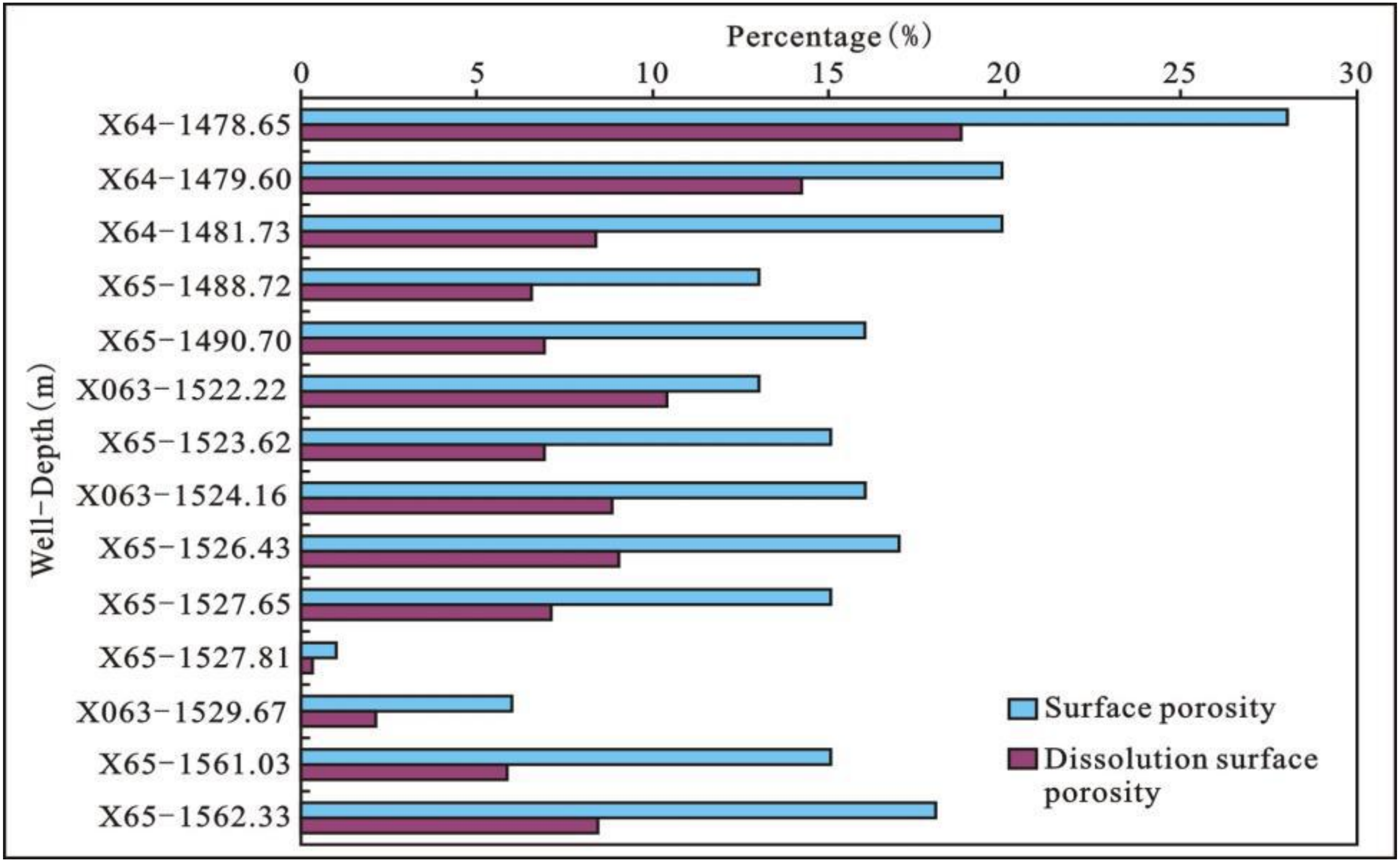

Figure 6. Diagram of surface porosity and dissolution surface porosity of unconformity semi-weathered rock layer.

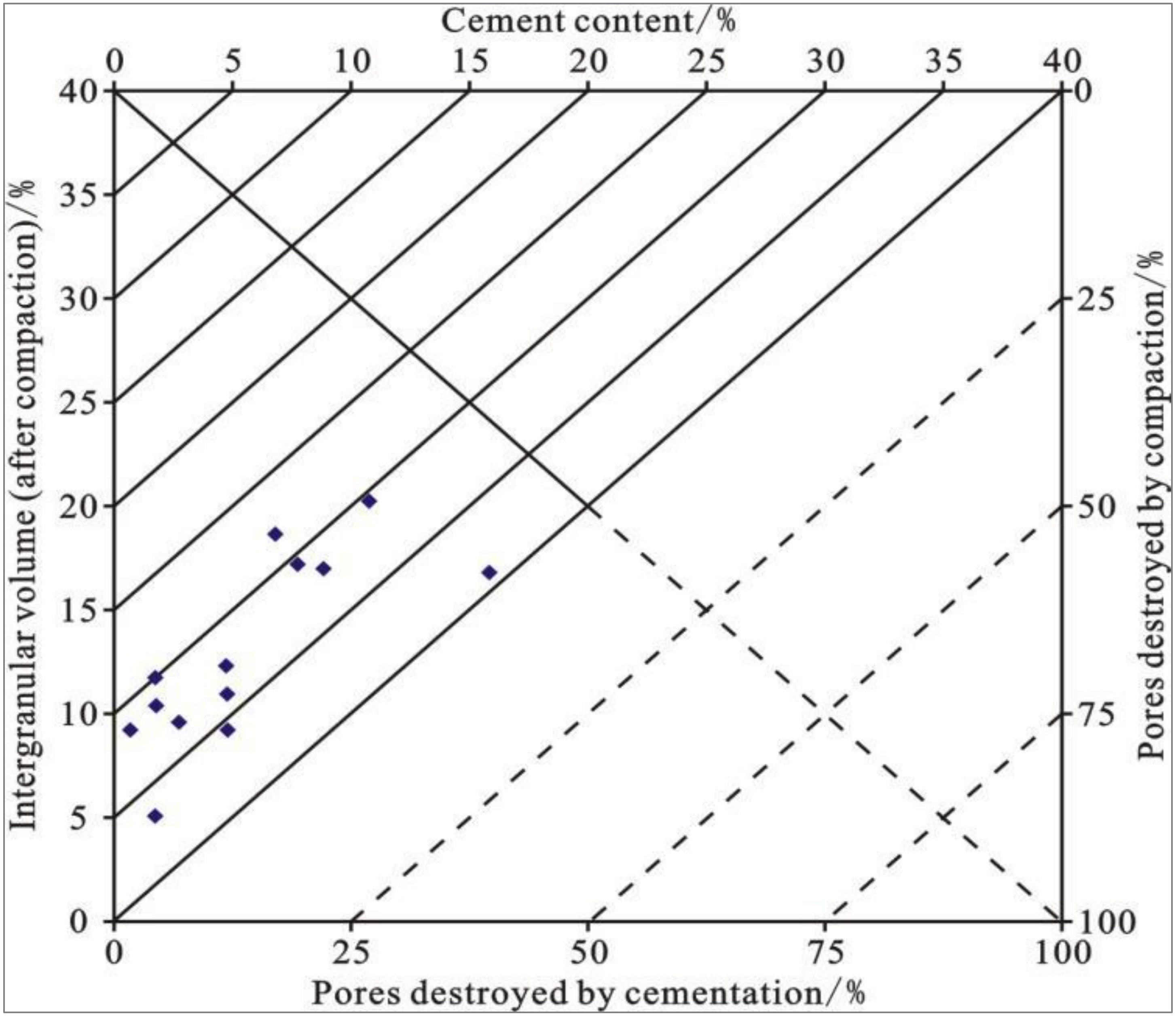

Figure 7. Evaluation map of relative intensity of compaction and cementation of the unconformity semi-weathered rock layer.

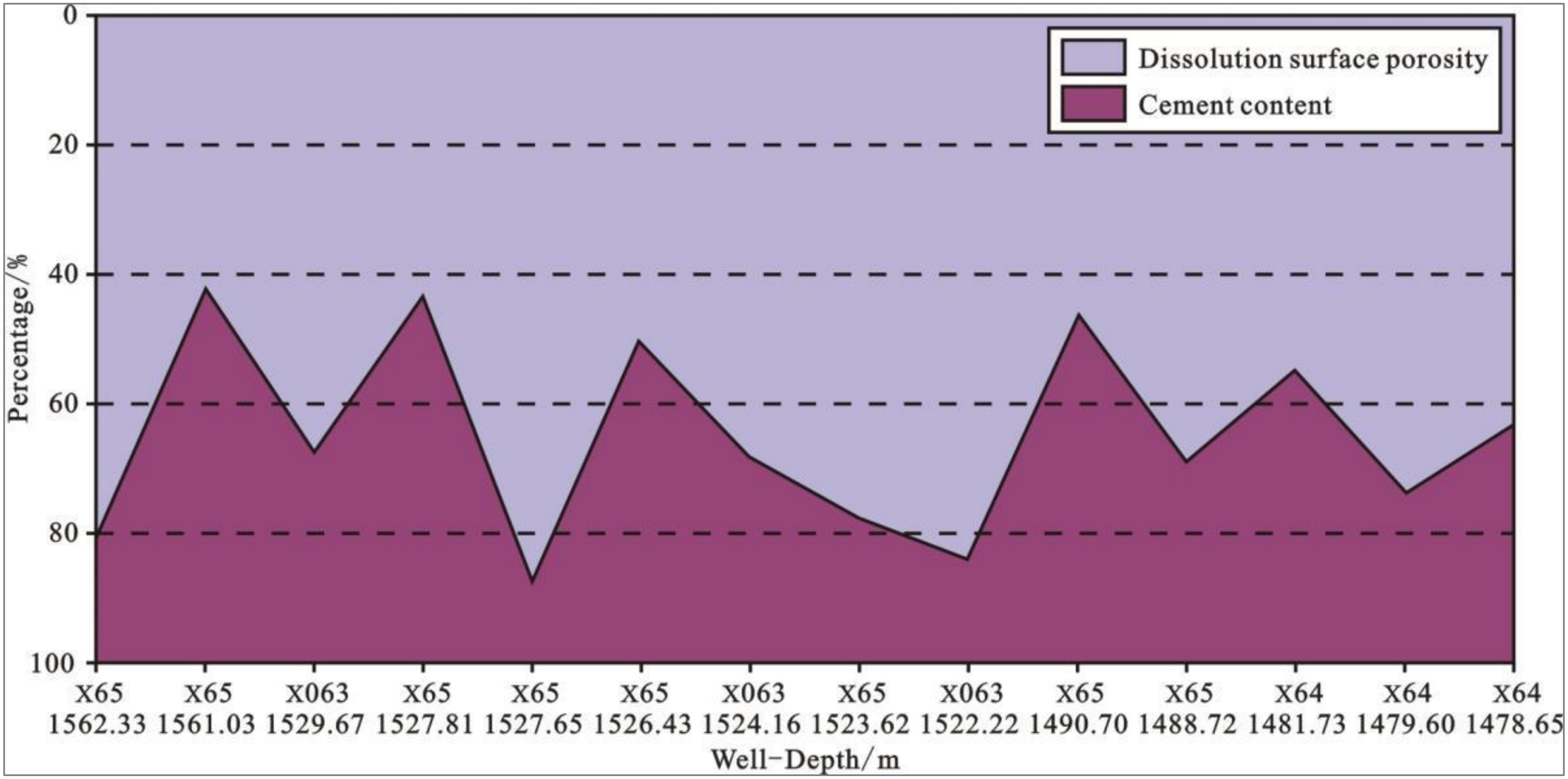

Figure 8. Evaluation map of relative intensity of dissolution and cementation of the unconformity semi-weathered rock layer.

Sample depth /m	Content of cement /%	Surface porosity /%	Dissolution surface porosity /%	Apparent compaction percentage /%	Apparent cementation rate /%	Apparent dissolution ability /%	Data sources
1478.65	11.00	28.00	18.76	49.40	54.35	23.52	Well Xia-64
1479.60	5.00	20.00	14.20	73.00	46.30	15.92	Well Xia-64
1481.73	7.00	20.00	8.40	53.50	37.63	10.32	Well Xia-64
1488.72	3.00	13.00	6.63	76.58	32.02	7.32	Well Xia-65
1490.70	8.00	16.00	6.88	57.20	46.73	8.30	Well Xia-65
1522.22	2.00	13.00	10.40	88.50	43.48	10.90	Well Xia-063
1523.62	2.00	15.00	6.90	74.75	19.80	7.68	Well Xia-65
1524.16	5.00	16.00	8.80	69.50	40.98	10.02	Well Xia-063
1526.43	9.00	17.00	9.01	57.53	52.97	10.85	Well Xia-65
1527.65	1.00	15.00	7.05	77.63	11.17	7.74	Well Xia-65
1527.81	16.00	1.00	0.34	58.35	96.04	0.41	Well Xia-65
1529.67	5.00	6.00	2.10	77.75	56.18	2.31	Well Xia-063
1561.03	8.00	15.00	5.85	57.13	46.65	7.06	Well Xia-65
1562.33	2.00	18.00	8.46	71.15	17.33	9.56	Well Xia-65

Table 1. Quantitative evaluation parameters of diagenesis of unconformity semi-weathered rock layer

Apparent compaction percentage /%		Apparent cementation rate /%		Apparent relative dissolution porosity /%	
Average value	67.28	Average value	42.97	Average value	65.00
Strength	Strong	Strength	Medium	Strength	Strong

Table 2. The strength evaluation results of diagenesis of unconformity semi-weathered rock layer.