Application of Spatial Database in Quantitative Analysis of Litho-Paleogeography—A Case Study of a Middle Ordovician Sequence Interval in the Ordos Basin

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Abstract In the study of sequence stratigraphy and litho-paleogeography, quantitative analysis, precise calculation and detailed comparison of tremendous geological data, such as field profiles, logging records and seismic curves from different areas, are the basic requirements. In order to obtain a more reliable and precise result, this paper presents a novel method that combines spatial database analysis with the single-factor mapping technology to establish sequence stratigraphical succession and to map the Ordovician litho-paleogeography of the Ordos Basin, one of the largest oil-gas bearing basins in North China Platform. By using this method, all of the related basic geological data can be quantitatively analyzed and effectively managed. Various attributes of the basic stratigraphic units and their characters, such as sequence thickness, penecontemporaneous dolostone content, shallow water parget content, and terrigenous material content, can be fully utilized statistically in facies analysis and in mapping. Based on this analysis, this paper has exerted single-factor isopachous mapping quantitatively for each of the Ordovician sequences in the basin, and finally synthesized multiple factors to reconstruct the litho-paleogeography for each of the sequence intervals. The study shows that the proposed method is quite effective and has a much higher resolution in recognizing litho-paleogeographic subunits compared with traditional ways. For example, in one of the Middle Ordovician sequence intervals (SQ19 in the Lower Majiagou Formation) of the Ordos Basin, the authors have successfully developed a mathematical formula to divide the distribution of various facies units substantially, such as old lands, submarine uplifts, supratidal zones, intertidal zones and subtidal zones.

Keywords spatial database; single-factor analysis; Ordos Basin; Ordovician; sequence stratigraphy; litho-paleogeography

Introduction

During the Cambrian and Ordovician period, the Ordos Basin was bounded to the east by the North China continental sea, to the west by the Qilian Ocean, and to the south by the Qinling Ocean. Affected by regional movements and the fluctuation of sea level, marginal marine or paralic sedimentation and cyclothem including carbonate rocks and plaster rocks occurred in this basin.\textsuperscript{[1,2]} It is of great significance to oil and gas exploration by researching deeply on the sequence strata and litho-paleogeography conditions of the early Paleozoic in this basin.\textsuperscript{[3]}
In the study of sequence stratigraphy and litho-paleogeography, a large amount of various data of different areas need to be analyzed and precisely contrasted to map the litho-paleogeography in sequences, which needs urgently a scientific and effective datum managing approach. How to store, manage, exchange, extract and analyze the geological data effectively is also the essential issue that geologic scientists extremely care about.

At present, the spatial database technology, which is a comprehensive database system to manage and analyze space data and position related attributive data, has been widely applied in the manufacturing and research field obtaining prominent effects. In the geological field, the spatial database has been launched and utilized widely worldwide, mainly prevailing on basic geological research, resource, environment management and mineral resource appraisement. As for the application of the relational database technology in litho-paleogeography, several scholars have already carried out theory exploration in some fields such as paleomagnetism and palaeontology. However, the relational database lacks a spatial analysis function. The spatial database is more powerful which sets the relational database in the spatial position. The spatial database can handle large quantities of data especially for paleogeography study which needs large geological data to compare and analyze in spatial position, and yet the application of the spatial database technology in litho-paleogeography has rarely been reported in the world. Therefore, we urgently need to find a useful method that can be applied in litho-paleogeography study.

So far, single factor and multifactor synthetical analysis are the most widely employed methods in litho-paleogeography study with abundant research results in China. Quantitative analysis is essential to the single factor method, whose expression is the single-factor contour chart. Many contour charts can be superposed and analyzed together. However, it is difficult for conventional methods to achieve quantitative analysis.

Mass data storage, management and contour chart mapping are basic functions in a spatial database system. The main aim of this paper is, by means of a special database technology, to analyze and map the litho-paleogeography of a third level sequence (SQ19) in the upper Majiagou Formation (about 464 Ma to 466 Ma) of the Ordos Basin, discussing especially the spatial database technology in single factor extracting, analyzing, contour mapping and multifactor comprehensive analyzing and mapping.

1 Spatial database establishment and single factor extraction

1.1 Quantization of geological data

Because of complexity and particularity, geological field records are usually obtained by way of qualitative observation so far. The records are often taken at random without any industrial standard, which makes it difficult to share with and exchange among geological workers. As a result, massive work is repeated and a great deal of funds is wasted. With the development of information technology, fieldwork records changing from qualitative to quantitative are an inevitable trend. In order to gain quantitative geological data, records need to be quantified and standardized. The simplest method of quantization is recording geologic field work quantitatively by the natural stratum. Records such as lithology, rock colors, layer thickness, formation state, granularity, depositing structures, fossils, special minerals, surface indicates, sample documents and photo documents, should be noted from each layer and the main information should be encoded. For example, common colors can be encoded according to their lightness; deposit structures can be encoded by surface characteristics; samples and photos can be numbered according to the strata, and lithology can be encoded according to certain naming rules. The record of lithology is the most important among all quantitative data, whose naming should follow the norm that should try to be simple and do not exceed the three-layer limit. For instance, the lithology description “interbedded strata of micrite, dolomite, limestone dolomite, dolomite limestone with mud shale and interlayered with marlrite” needs to be divided further. The description “micrite with mud shale interlayered with marlrite” is according to the three-layer naming norm, but it should point out the proportion of layers clearly, such as 10:1 for interbedding and 4:1 for in-
ter-layering. In the same way, colors also need to be named simply, with no more than “two layers”. The description like “grayish green” and “yellow-gray” conform to the norm, but the description like “yellow and grayish green” or “grayish yellow and grayish white” should be avoided. If the same stratum has different color names, the stratum can be divided further.

### 1.2 Establishment of the spatial database

The spatial database is made of spatial data tables and several attribute tables. A profile name form is the only spatial data table that mainly stores profile position information in this article. There are several attribute tables in this article (Fig. 1).

#### 1.2.1 Establish spatial data tables

The profile name form which includes profile number, profile name, profile place, longitude, latitude, bar chart number, etc., is established in order to confirm the position of each profile in the geographical space.

#### 1.2.2 Establish attribute tables

Various attribute tables are constructed according to the logic relations illustrated in Fig. 1, and relevant quantitative data are organized into each attribute table.

### 1.3 Extraction of single factors

Various single factors can be calculated or summarized by using the spatial database technology after inputting the quantitative stratum data into the attribute data tables. This paper takes the third-level sequence as the basic statistical unit to classify and calculate the data. Many factors such as sequence stratum thickness, average color value, shallow water terrigenous deposit content, penecontemporaneous dolomite content, shallow water parget content, shallow water carbonate particle content, plaster content, rock salt content, sub-sequence number and ratio of sub-sequence upper unit to lower unit can contribute to the single factor analysis.

Sequence thickness is easy to be counted by calculating the thickness of all layers of the sequence in every profile. The sequence thickness of every profile is the sum of every layer thickness in one profile.

The determination of average color value is much more complicated than sequence thickness. First,
the number of colors of all layers in the sequence of each profile needs to be counted. Second, the name of every color is standardized. Finally, we assign a value to every color depending on its deoxidization or oxidation order. The color values were used according to the order as shown in Table 1.

| Color   | Black | Green | Dark gray | Gray | Orange | Ashen | Bister | Dark red | Brown | Mauve | Land |
|---------|-------|-------|-----------|------|--------|-------|--------|----------|-------|-------|------|
| Color value | 1 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 | 0.4 | 0.3 | 0.2 | 0.1 | 0 |

The formula of average color value of each sequence is: average color value = sum (thickness of layer 1 × color value of layer 1 + thickness of layer 2 × color value of layer 2+ ...+ thickness of layer n × color value of layer n + ...)/sum (thickness of layer 1 + thickness of layer 2 + ...+ thickness of layer n + ...). Therefore, the average color value of every profile can be easily acquired by database batch computing.

The content of each component, such as terrigenous deposit, penecontemporaneous dolomite, shallow water clastic rocks, shallow water carbonate particle, plaster and rock salt, need to be analysed in detail indoors. The determination of the content under the microscope has prevailed for a long time. The lithologic names under the microscope are determined through percentages of various compositions of every type of sample, with which the lithologic names from fieldwork are compared. Then, the names of each type are corrected and their composition coefficients are set up. For example, the sample S-002 has been named dolomite limestone in the field but the determination result under the microscope is that the content of dolomite, micrite, and terrigenous mud is 5%, 70% and 25%, respectively. Then this kind of rock should be corrected to dolomite mud limestone in unison through spatial database batch modification. Then the target coefficient of this type is 0.70, penecontemporaneous dolomite coefficient is 0.05 and terrigenous deposit coefficient is 0.25. If the particle content is 12% in this kind of rock, then the particle coefficient is 0.12. All lithologic character coefficients are put into a lithologic character coefficient form of the spatial database (Fig. 1).

Then the thickness and content of the single factors in each stratum can be calculated in each profile by the database analysis combining the lithologic character coefficient form with the measured profile form.

According to lithologic characteristics, lithofacies, fossils, depositing structures, strata laydown mode, etc., sub-sequences are distinguished and the number of sub-sequences is counted in each sequence.

After the upper and lower parts of each sub-sequence have been identified and their thickness has been counted, total thickness of the upper and the lower units of all sub-sequences in the sequence can be calculated. The total thickness of lower units divided by the total thickness of upper units is the average content ratio coefficient of upper and lower units of the sub-sequence in each sequence.

While single factors of each sequence in every profile are organized into the table, a single factor statistical table of sequences is formed.

2 Application of the spatial database

2.1 Space positioning of data

Longitude and latitude in the profile name forms are the two attributes specially used to project the profiles spatial location. A lot of GIS software such as MapInfo or ArcGIS integrate computer graphics and data management technology fully. Therefore, relevant attribute data and space positions are established direct relations for every field profile and well logging profile, which provides convenience for special inquiry and analysis for geological data. Fig.2 shows the position map of all profiles in the study area.

2.2 Space data inquiry

Scientific management, prompt inquiry and calculation are the basic functions of a database management system. In litho-paleogeographical research, researchers need to filter the objective basic data repeatedly, and to inquire, display, and contrast it in spatial position. For example, now it is easier to in-
quire the profile where mud shale shows up in sequence SQ19, amount of mud shale layer in sequence SQ19 in Shanxi Zhongyang profile, and the strata of the sequence where fossils are collected. All these offer effective evidences for the sedimentary facies analysis and litho-paleogeography study.

2.3 Single factor contour mapping

Fig. 2 shows that comprehensive single factor data of 18 field profiles, 185 logging profiles and 15 artificial...
supplementary points are projected. Every single factor has been extracted by the spatial database system and every single factor contour chart of each sequence has been drawn through the spatial database software such as ArcGIS. Fig. 3 shows the single factors contour chart of the SQ19.

2.4 Single factor analysis

2.4.1 Thickness analysis of the sequence

In a specific geological period, the stratum thickness of sequences is mainly affected by subsiding and sediment inputting in deposit areas. The sequence thickness contour chart reveals a tectonic framework for evaluating and understanding processes responsible for the deposition scope of the sequence and the litho-paleogeographical pattern, such as the distribution of relative concave areas and upheaval areas, or deposit areas and corrosion areas.

In order to accurately depict the litho-paleogeography pattern, it needs to be combined with the litho-paleogeographical background and the neighboring stratum characteristics at that time.

Sequence SQ19 developed perfectly in most areas of the Ordos Basin with shallow carbonate and mixed carbonate clastics, mainly of dolomite, micrite, mud shale, plaster rock and salt rock, indicating that typical supratidal zone-lagoon deposits dominated in most areas of the basin in this interval.\(^{[39-41]}\)

The Mawu sequence represents a time when the relative sea level was near its minimum in the Ordovician. After the largest marine transgression happened in the Masi period, an extensive marine regression deposited in the Ordos Basin during the Mawu period of the Ordovician, followed by an obvious transgression in the Maliu period. The Mawu Formation can be compared in full scale.\(^{[2,39]}\) There was little possibility that the Mawu stage deposit was eroded because no upheaving records prove it. In the Mawu period, there were almost no terrigenous deposits in the Ordos Basin, where the deposit thickness is zero and deposit is basically dolomite and dolomite limestone in its edges, except around the Dongsheng old land, Qingyang old land and several fragmentary areas in the Ningxia Province and north Shanxi Province. From the direction far from old lands, deposit thickness and terrigenous sediment content are obviously increasing. Therefore, researchers infer that the zero deposit thickness areas of SQ19 was old land, and deposit thickness of stratum gives a direct suggestion on the topography. Fig. 3(a) shows obviously that the Dongsheng old land is located in the north of the Ordos Basin, Qingyang old land in the south, Pingliang-Weishui depression basin in the southwest, Helan depression basin in the west, North Shanxi depression basin in the center, Xing County depression basin of Shanxi Province in the east, Yimeng depression basin in the northeast, gentle slope of Shanxi Province in the southeast, and submarine uplifts in Well 1 of Renqiu and Well 47 in Shanxi Province.

2.4.2 Shallow water terrigenous deposit content analysis

Shallow water terrigenous deposits comprise breccia, conglomerate, sandstone, siltstone, mud stone and shale. Terrigenous deposits can be further divided into coarse terrigenous detrital rocks and fine terrigenous detrital rocks. Coarse terrigenous detrital rocks mainly include breccia, conglomerate and sandstone which deposit on the edge zones of old lands, whose compositions and structures are important in identifying rock compositions and terrains of old lands.\(^{[1,32-36]}\) Fine terrigenous detrital rocks comprise shallow water siltstone, mud stone and shale. Because of their tiny particles, they can be carried far away and then deposited mostly in quiet water environments. As a result, the shallow water terrigenous content is related to the old land positions, terrigenous source direction from old land and transgression direction of the sea on the whole. Tidal flats where siltstone and clay rock distribute widely can serve as important evidence for environments close to old lands in paraplain old land.\(^{[40-48]}\)

The thickness contour chart in Fig. 3(b) shows that shallow water fine debris deposits were dominant in SQ19 terrigenous material. The areas close to the Qingyang old land and on both sides of the Dongsheng old land generally lacked of terrigenous deposits, which indicated that sea water had not flooded the old lands yet. In Well 47 of Shanxi, Well 9 of Hubei, Well 1 of Renqiu and Liulin area in Shanxi Province,
the terrigenous deposit thickness is small and terrigenous content is relatively low, which suggests that sea water had just flooded these uplifts at that time. Because terrigenous material was carried to far places, only a small amount was deposited close to old lands. The most abundant area accommodating terrigenous debris deposits is on the gentle slope of Shanxi in the southeast, whose thickness can reach up about to 8 m to 16 m with terrigenous content up to 13% to 25%. The second area is the Xing County depression basin in Shanxi, with the thickness from 9 m to 16 m, the content from 10% to 15%. In the Zhuozi mountain depression basin, Helan depression basin and Pingliang depression basin, the terrigenous debris thickness is relatively low, generally from 4 m to 10 m, with the content less than 8%. In north Shanxi Province, because of the bad connectivity to the sea and the big distance from the old lands, only a small amount of terrigenous debris deposited in a lot of deeper sags which were most of restricted basins. Therefore, its thickness is from 2 m to 4 m and the content is mainly from 2% to 5%, only at the bottom of several sags is about up to 10%. Between Helan depression basin and Pingliang depression basin, terrigenous deposit thickness is only about 2 m to 4 m and the content is only about 1% to 5%. Those characteristics indicate that transgressing direction was mainly from southeast to northwest in the study area. In the southeast, material coming from old lands covered the slopes because of the good circulation with the open sea and the strong erosion of old land by waves and tides although the terrain sloped gently. Some areas did not open well into the ocean or were far away from the source supply zones (old lands) or nearly exposed to the surface, so it was difficult for clastic rocks to deposit.

Fig.3  Contour maps of all factors of SQ19 in the Ordos Basin

2.4.3  Penecontemporaneous dolomite content analysis

Penecontemporaneous dolomite is a kind of shallow water carbonate rock with tiny crystalline grains. It is often accompanied by sedimentary structures of schistose stratification, stromatolite, rock salt pseudocrystal and plaster, which correspond closely with the characteristics of supratidal zones. It is an important evidence to distinguish dolomite flat, mud dolomite flat and dolomite mud flat which are often restricted to the edges of aged period old lands where the terrain is gentle. Consequently, it is generally be-
lieved that tidal flat deposition environments such as dolomite flat, mud dolomite flat and dolomite mud flat only occur near old lands. [43-48] The terrigenous debris of SQ19 is all fine terrigenous debris instead of coarse debris, which indicates that the slope gradient of old lands in the interval was relatively gentle and the lands might have been exposed a very long time with its topography being almost pediplanation. Aged period old lands are characterized by appropriate topography so that dolomite can deposit.

Fig. 3(c) shows that the Pingliang depression basin is located in the southwest of the Ordos Basin, the depression basin of north Shanxi Province in the center, and Xing County depression basin in the east. In those areas dolomite deposit thickness is relatively high, about 80 m to 180 m and the content is relatively high too, about 55% to 85%. These areas formed supratidal zone lagoons since they were basically isolated from the sea. In other areas, dolomite deposit thickness is about 20 m to 40 m with the deposit nearly covering the whole basin, which indicates that most areas situated in subtidal zones or intertidal zones. On the gentle slope of Shanxi in the southeast and Zhuozi mountain depression basin in the northwest the content of dolomite is about 40% to 60%. In those areas deposit was speculated to accumulate in subtidal zones or intertidal zones. The content of dolomite is only small between western Pingliang and Helan mountain in Ningxia Province with the content less than 20%. It means that subtidal zones probably developed in the western borders of the sea.

2.4.4 Shallow water parget content analysis

The parget content can be regarded as an important reference to distinguish dolomite flat, dolomite limestone flat, mud flat, mud dolomite flat and carbonate platform. [1,33-39] Fig.3(d) illustrates that the parget content of SQ19 is relatively high, about 40% to 90% in Shanxi’s gentle slope in the southeast of the basin, while it is about 40% to 85% at Qinglong Mountain area in Ningxia. Because terrigenous mud content in the gentle slope in Shanxi was relatively high and the slope was at a short distance from Qingyang old land and the slope’s northwestern direction is the direction of transgression, it can be inferred that the deposit environment on the slope was mainly subtidal zones. The topography of the Qinglong Mountain area in Ningxia was smooth with low dolomite content, relative high parget content, and less terrigenous material content, so it also developed in subtidal zones.

2.4.5 Plaster content and salt rock content analysis

Plaster rock and salt rock were generally distributed on the evaporation environments like lagoons and dolomite plain environments whose main minerals are plaster, anhydrite and rock salt. Plaster rock and salt rock widely prevail in the Mayi, Masan and Mawu formations in the middle east of the Ordos Basin. [1,2,22] Among them, the salt deposit of Mawu Formation in the depression basin of north Shanxi Province was especially thick, forming good caprock for oil and gas fields. [40-41] In Xing County and Well 46 in Shanxi Province, the thickness of SQ19 is about 8 m to 18 m and the plaster’s content of SQ19 is from 15% to 65%. The content of plaster is up to 50% in the area within 5 km around Well Shan46, so this area can be named supratidal zone plaster lakes, while the area from 5 km to 12 km from the Well Shan46 can be called plaster-containing lakes. In Xing County of Shanxi Province, the plaster content is low, about 2% to 8%, so this area is not given a single name. During SQ19, rock salt mainly occurred around the regions of Well Yu9 in Suide with a thickness of about 30 m to 100 m and a content from 15% to 55%. The rock salt content can be up to 40% to 55% within 3 km from Well Yu9, so this area can be called the salt lake, while the area from 3 km to 8 km around Well Yu9 can be called saline containing lakes.

2.4.6 Other factor analysis

The average color value of the sequence can reflect the distribution pattern of oxidation and deoxidation environment; the sub-sequence number can indicate the reflection sensitivity of the deposit environment to sea level changes; the average thickness ratio of upper units and lower units of sub-sequences can reveal how much the sea level had changed and how long it took to deposit, and single factor analysis results can serve as important signs to identify litho-paleogeographical units.
3 Data analysis and litho-paleogeography mapping

3.1 Division of litho-paleogeographical unit

According to the single factor analysis results above, litho-paleogeographical units have close relations with penecontemporaneous dolomite, parget and terrigenous content in the study area. In general, the dolomite content is relatively high in supratidal zones, the parget content is relatively high in subtidal zones and limestone content is close to intertidal zones, while terrigenous material generally concentrates in subtidal zones. This article defines the areas with dolomite content of more than 60% as supratidal zones, the areas with parget content of more than 60% as subtidal zones, while the areas between them is defined as intertidal zones.

After repeated experiments and theoretical derivation, the researchers have summarized an empirical formula value to distinguish supratidal zones, intertidal zones and subtidal zones. The formula is:

$$F(x, y, z) = \{x + y + \lfloor 0.01 \rfloor / \lfloor 0.01 \rfloor \} \times 4 + 0.2 + 4z$$

where \(x, y, z\) represent penecontemporaneous dolomite content, parget content and terrigenous material content, respectively. “[]” shows conditions: the first \([0.01]\) means that if parget content plus terrigenous content equals 0 but the sequence thickness is not 0, it needs to add a 0.01 to distinguish from old lands whose value is 0; the second \([0.01]\) shows that when sequence thickness is not 0 but the content of dolomite is 0, it needs to add 0.01 to avoid being divided by 0; 0.2 is a rectificatory value; the number 4 outside the mark “}” shows that the value in the mark “}” should not exceed 4, if it does, fix 4 to make it more convenient to analyze the contours.

\(F(x, y, z)\) has been used to calculate results in SQ19 for all profiles based on the database and the contour chart is shown in Fig. 4. In the picture, 0, 0.8, 2.6 served as thresholds to distinguish old lands, supratidal zones, intertidal zones and subtidal zones. In the contour chart, areas where the \(F\) value equals 0 were old lands, the \(F\) value between 0 to 0.8 were supratidal zones, the \(F\) value between 0.8-2.6 were intertidal zones and the \(F\) value more than 2.6 were subtidal zones (Fig.4).

3.2 Litho-paleogeography mapping

Litho-paleogeographical mapping is one of the most important expressions for litho-paleogeographical study results, which reflects main litho-paleogeographical features of the area. According to the division principles of litho-paleogeographical borders described above, as well as geological background and structural evolutionary characteristics of this area, the litho-paleogeographical map of sequence SQ19 in the Middle Ordovician interval was drawn as shown in Fig. 5.

Fig.5 illustrates that supratidal zones were distributed around two old lands, where the content of dolomite was from 60% to 90%, the content of parget from 10% to 40% and the content of terrigenous from 1% to 5%. Supratidal zones were filled with dolomite, plaster and salt rock. Intertidal zones were around supratidal zones, where the content of dolomite was from 40% to 60%, the content of parget from 40% to 60% and the content of terrigenous from 3% to 10%. Intertidal zones were filled with calcareous dolostone, dolomite limestone and marlite. Subtidal zones were found in areas of Helan Mountain of Ningxia-Qinglong Mountain in the west and Hejin of Shanxi Province in the southeast, where parget content was from 60% to 80%, dolomite content from 20% to 30% and terrigenous deposit content from 10% to 25%, mainly of micrite, ooid containing limestone, dolomite limestone, dolomite containing limestone, marlite and mud shale. Subtidal zones located in the
west of Ningxia and the Qinglong Mountain, in the southeast of Hejin in Shanxi Province, where the content of parge was from 60% to 80%, the content of dolomite from 20% to 30% and the content of terrigenous deposit from 10% to 25%. Carbonate sedimentation predominated in subtidal zones, including micrite, containing ooid limestone, dolomite limestone, sometimes containing dolomite limestone, marlite and mud shale. It is speculated that it is high in the east and low in the west. There are two transgression directions: one was from southwest to northeast while the other from west to east, which meant sea water might come from two different sea areas.

![Fig.5 Litho-palaeogeographical map of SQ19 sequence in Middle Ordovician in the Ordos Basin](image)

4 Conclusion

The use of a spatial database achieves scientific management of massive geological data, through the field record quantitative processing, massive single factors extraction, contour mapping, quantitative analysis, special contrast and multi-factor spatial overlay analysis, thus ultimately making the quantitative lithofacies paleogeography map compilation come true. The application of spatial database technology, compared with traditional research methods, in terms of the accuracy of data applications, intuitiveness, objectivity, and improvement of efficiency, has obvious advantages, so it may be a viable research method.

After repeated experiments, we obtained an empirical formula to divide supratidal, intertidal and subtidal zones, which move forward on the basis of previous “quantitative” methods. With further study, the use of spatial database analysis and management technology enables automatic analysis and mapping of the final lithofacies paleogeography.

5 Discussion

Some of the single factors that need to be extracted
urgently, such as particle size value of carbonate, carbonate rock-like (thin, middle, thick, massive) value, the value of marine fossils, sedimentary structures and other values could not be obtained due to the limitations of the field data character, but these single factors are essential for the restoration of the paleogeography.

Since any single factor only offers part of all geological information, more information with further research should still be constantly updated. If the field records were unified, standardized and quantitative, a lot of geological information will be available to obtain through mathematical statistics and calculation. Perhaps the geological history of the individual “code” can be deciphered through simple mathematical methods.

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