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Research progress of fibrous layered veins

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Abstract

Fibrous layered veins often appear in shale and carbonate formations. The formation mechanism and the formation of cone-shaped structures in them are of great significance to the diagenetic sedimentary environment of surrounding rocks and the geological history of surrounding rocks. In the past, scholars generally used the fracture closure mechanism to explain the formation process of fibrous veins. However, with the discovery of anti-axial tensile veins, the fracture mechanism cannot fully explain its causes. Therefore, it is necessary to further explore the formation mechanism of fibrous veins. Based on previous studies, this paper collected and analyzed the literature related to fibrous veins, and comprehensively described and analyzed the research status, crystal structure classification, material migration mechanism and different genetic interpretation types. It provides a comprehensive understanding of the formation mechanism of different types of fibrous veins. It also provides an important reference value for understanding the origin and evolution process of fibrous veins and cone-in-cone structures in the formation. At the same time, this paper summarizes and analyzes that the crystal morphology of many fibrous veins cannot be explained by the classical crystal growth theory. Some recent studies have also shown that veins can be formed without rupture. Under the mechanism of diffusion and mass transfer, crystal growth forces the separation of surrounding rock and may form unruptured veins.

Keywords

Fibrillar Veins; Reverse-Axis Tensile Vein; Cone-In-Cone Structure; Genesis Mechanism

1. Introduction

The fibrous layered parallel veins are also called beef veins, which are also called FCV and BPV. It was originally an old quarry term. In the 19 th century, British quarry workers found that the parallel fiber structure of calcite and gypsum was similar to beef fiber during their work. Therefore, in the past geological publications, this fibrous layered parallel vein was called beef vein. In the early literature of Lang and Richardson, it was also described that there were two kinds of fibrous diagenetic calcites in limestone, namely ' BEEF 'calcite and ' cone in cone 'calcite. The ' cone in cone ' calcite is also known as the cone structure in the domestic literature. The cone structure is also composed of fibrous minerals, which are composed of fibrous or leaf-like crystals. These crystals form conical aggregates in the rock. It often appears in the nodular or vein-like accumulation of millimeter to centimeter thickness, extending in parallel with the bedding of surrounding rock ; the cone tip is up or down. The coning structure is significantly different from the shape of the fibrous layered veins, and its size is smaller and more complex (Hessen et al, 2019). In the past literature, it was described that it was usually composed of a series of concentric right cones, stacked one by one in a more or less vertical way. They are usually composed of two layers of cones, the inner cone is usually a thin shell (Kowal, 2010), and the outer cone is composed of a thicker shell (Paul C, 1969). The reasons for the formation of these structures are still controversial. The crystalline C-axis of fibrous layered veins is parallel to each other (or grows at a small angle). The veins are usually a few centimeters wide, and tens of meters (or hundreds of meters) long are symmetrical to the central suture (dark), along which the original stratum can be seen. It often occurs in organic-rich black shale and limestone basins. It is common in or near petroleum source rocks.

The description of the conic structure and the debate about its origin can be traced back to the 18 th century. The most important question in the study of the cone structure is whether the mineral is precipitated in its cone shape or formed after precipitation. According to the term of Sellés-Martínez (1994), the former hypothesis is called the primary cone-in-cone here, and the latter hypothesis is called the secondary cone-in-cone.

Up to now, there has been no relatively consistent view on the petrological origin of the two hypotheses on the conic structure. On the contrary, due to the different diagenetic environments, the views of scholars are contradictory. And these two competing assumptions are questioned due to the lack of explanation of the cone shape. And for the primary cone, it is not clear why triangular minerals with fibrous or leaf-like habits form cones. The cone angle of different samples varies greatly. The typical cone angle ranges from 50 ° to 70 °, but Woodland (1964) and Franks (1969) pointed out that in coarse-grained host materials, the cone angle is wider, up to 100 °. Both studies have concluded that the cone angle is not related to the diamond cleavage of calcite.

Fibrous lamellar veins are a special kind of veins, because they provide a record of the change path when the veins are formed. The veins in rocks have been studied for more than 150 years. Initially, scholars were interested in how veins were formed. Veins provide information about how fluids migrate in the crust and how these fluids transfer material. The types of veins are very rich, from the huge quartz veins of Brazil and Australia (Hippertt and Massucatto, 1998 ; bons, 2001) to mineral-rich microfractures (e.g. Ramsay 1980 ; mullenax and Gray, 1984) and from planar veins to pressure stripes (Durney and Ramsay, 1973). The diversity of vein types and their internal structures indicates that there is no single mechanism that can explain the formation of all veins. The existence of fibrous layered veins and the fluid inclusions carried in them in the surrounding rock is of great value for revealing the formation environment of the surrounding rock, the state of the ancient stress field of the rock mass at that time and restoring the ancient climate at that time. Because the microstructure of the vein can also indicate its relationship with the seismic event, the mineral source of the vein related to the seismic activity is mainly from the external fluid, and its geochemical characteristics are obviously different from the surrounding rock, so the study of the vein in the fault area can also understand the regional seismic behavior and cycle. After nearly two centuries of research, scholars have studied and observed the morphology of fibrous veins from macro to micro. For the genetic mechanism of fibrous veins, scholars have put forward different views (from crack closure mechanism to advection diffusion). In the papers of Durney and Ramsey (1973) and Ramsey (1980), the authors recorded some fibrous minerals (quartz, calcite, feldspar, actinolite, biotite, chlorite) in the metamorphic grade to the upper greenschist facies. In the extensional veins of deformed rocks. The inclusion bands with regular orientation and spacing on these mineral fibers are interpreted to indicate that the fiber-to-slender massive vein structure is formed by fracture closure. Based on this study, the crack-sealing mechanism of fiber vein formation was proposed.

The research work of Durney and Ramsay (Zhao, 2022), Ramsay (Durney, 1973) and Huber as well as Passchier (Passchier C.W, Trouw R.A.J, 1996) and Trouw determined the term of fibrous vein structure and its interpretation of tectonic movement. Since Ramsay introduced the fracture-closure mechanism, especially those slender and fibrous veins, have been explained according to this mechanism. However, Bons believes that not all fiber veins are formed by the fracture mechanism.

Many studies have shown that fiber veins are the result of brittle failure, crack expansion, fluid penetration, and subsequent mineral precipitation. However, some recent studies have also shown that veins can also be formed without fracture, and the growth of veins is driven by the material diffusion transport of direct surrounding rock. Under the diffusion mass transfer mechanism, crystal growth forces the surrounding rock to separate rather than form through the crack-sealing mechanism. The mechanical research on the formation mechanism of fibrous veins is mainly derived from the experimental simulation of mechanical models in the 1990s, from the widely accepted Coulomb Mohr mechanical mechanism of rock fracture fracture to the fracture mechanism of overpressure fluid. In recent years, with the continuous development of geochemical methods and the development of high-precision and high-resolution laser ablation technology, fibrous veins can get better microstructure observation and material genesis analysis. In recent years, there are scholars at home and abroad (Wang, 2016 ; bons et al., 2012 ; bons and Montenari, 2005 ; zhao, 2022) used some high-precision laser ablation techniques to observe and analyze the microstructure of the vein to characterize the mineralogical and crystallographic characteristics of the fibrous calcite vein and analyze its material source.

For the cone structure, scholars have proposed the mechanism of the formation of biomineralized crystalline aragonite fans, which may be closely related to the changes in the marine environment. However, the explanation of the genetic mechanism of these views in different sedimentary environments is still controversial. There is still no relatively complete explanation for the genesis of fibrous layered veins and cone-shaped structures. Therefore, scholars still need to further explore the genetic mechanism of fibrous veins. This paper will review the research progress and significance of the genetic mechanism of fibrous layered veins. Scholars should combine geochemical methods with petrography in order to better analyze the genetic mechanism of fibrous layered parallel veins from multiple perspectives.

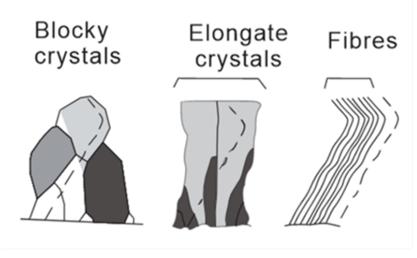

Figure 1: Comparison between Fibrous Vein Body and Common Vein Body Types

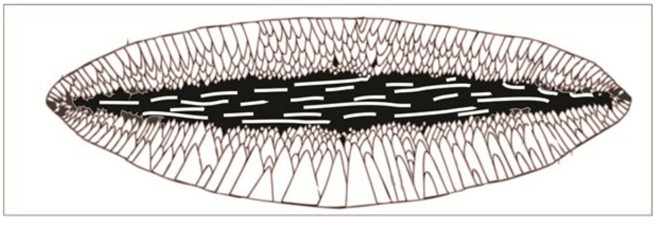

Figure 2: Schematic diagram of the conical structure of an elliptical nodule cone from the Upper Devonian of the Candaway Formation in western New York, with the axis of the cone perpendicular to the shale bedding plane

2. Type classification of fibrous lamellar veins

In the papers of Durney and Ramsey (1973) and Ramsey (1980), the authors recorded some fibrous minerals (quartz, calcite, feldspar, actinolite, biotite, chlorite) in the extensional veins of metamorphic grade to upper greenschist facies deformed rocks. Based on this research, the crack-sealing mechanism of vein formation is proposed.

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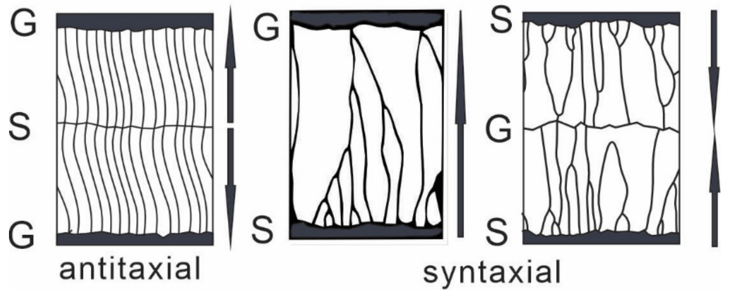

Figure 3: Shows three common types of fibrous veins, where S represents the starting surface of crystal growth and G represents the extending surface of crystal growth. The arrow indicates the direction of crystal growth, where a represents the anti axial stretching vein, b represents the stretching vein, and c represents the radial stretching vein

1.1 Stretched pulse veins

The -stretched vein is a vein formed by the crack closure mechanism, which is formed by multiple crack closures. However, due to the different positions of crack closure during crystal growth, it has multiple crack growth surfaces, which is also different from the radial vein. There is no competitive trend in the growth of crystals during its formation. The crack surface can penetrate the previously formed veins to form local tensile veins, and even penetrate the surrounding rock wall to form discrete tensile veins. Its crystal growth is usually serrated. Due to the uncertainty of the opening of its growth surface, it is impossible to determine the direction of its crystal growth.

1.2. Syntaxial veins

The syngenetic vein is a vein that grows out of the surrounding rock cracks. The minerals filling the vein come from its surrounding rock, so the vein body usually has the original rock mineral composition. Its growth is usually from the outer wall of the vein to the middle of the vein, but occasionally some of the vein growth is from one side of the vein wall to the other side of the vein wall. Therefore, the syngenetic vein has a single crack growth surface, and its growth surface is usually in the middle of the vein crack, and its single crystal has optical continuity. The crystal growth from both sides of the vein to the middle may have experienced multiple crack closures. The single growth surface leads to the inhibition of its crystal growth competition, and the nucleation process of its crystal is usually inhibited, because its energy is not as much as the energy obtained by expanding the existing crystal, that is, the growth competition of its crystal is inhibited. As the crystals grow side by side in the same direction, the crystals become slender in the growth direction. The different growth rates of individual crystals lead to growth competition, some of which grow faster than others (Okamoto, 2011 ; bons et al., 2012 ; bons and Montenari, 2005). The result is an array of elongated or leaf-like crystals, some of which are growing

1.3. Antitaxial veins

The dorsal vein is also known as the anti-axial tensile vein, and its formation mechanism is still the least understood. In the original definition of Durney and Ramsay, the crystals in the anti-axial vein ' have optical continuity in the whole vein and grow from the middle suture to the surrounding rock wall ', while the ' vein filling in the tensile vein is the overgrowth of the original surrounding rock mineral particles and has optical continuity '. The crystals of the dorsal vein are usually fibrous crystals, sometimes with extreme aspect ratios, so they are called fibrous veins in the strict sense. The characteristic formula of the dorsal vein body has a midline or an intermediate marker band. Through the intermediate marker band, the crystals that form the dorsal vein grow in opposite directions, so they have two growth surfaces and have certain symmetry. However, due to the different growth rates of the two growth surfaces, they may also be asymmetric (Oliver and Bons, 2001).

3.Study on the genetic mechanism of fibrous layered vein and cone structure

1.1. Overpressure theory explains the formation mechanism of fibrous veins

The formation of vein cracks in rock strata is mainly due to rock fracture, and the fracture of rock mass usually follows Mohr-Griffith-Coulomb criterion. The stress state of the rock fracture boundary can be displayed on the Mohr-Griffith-Coulomb fracture envelope. The Mohr diagram indicates that all possible combined Mohr diagrams are a two-dimensional diagram, only considering the stress components on the two-dimensional plane, including the maximum principal stress σ1 and the minimum principal stress σ3 acting on the plane, represented by the horizontal axis. The Mohr-Griffith-Coulomb and fracture envelope function graph forms a plane stress state boundary, in which the rock can be represented by all normal stresses σn and vertical axes on the plane to represent the shear stress τ (Figure 5). All possible combinations of the shear stress τ and the normal stress σ of a given plane lie on a circle centered on the horizontal axis, which contains σ1 and σ3. Each point on the Mohr circle represents the stress state of a point on a plane to maintain stability. When the Mohr circle is tangent to the fracture envelope, the internal stress balance of the rock is broken, and the fracture occurs, which represents the formation of cracks in the rock mass. Any σ-τ combination outside the envelope is impossible because the rock cannot maintain such a stress state and will fail.

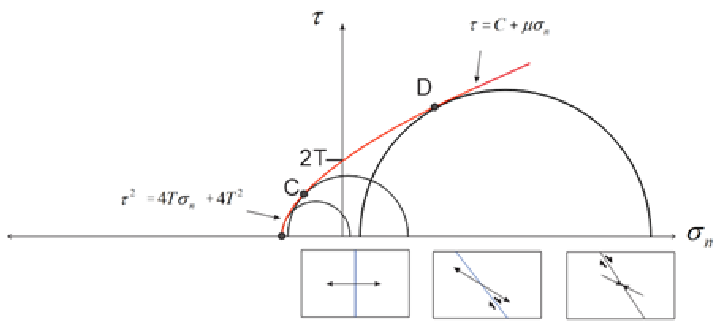

Figure 4. Mohr Coulomb fracture criterion for rocks

In the case of very high deep confining pressure, tensile failure occurs only when the fluid or melt pressure increases. The fluid pressure is opposite to the static rock pressure and needs to be considered. In order to do this, the fluid pressure is inferred from the actual stress, which effectively moves the Mohr circle to the left, and the effective stress becomes σ1-Pf, σ3-Pf.

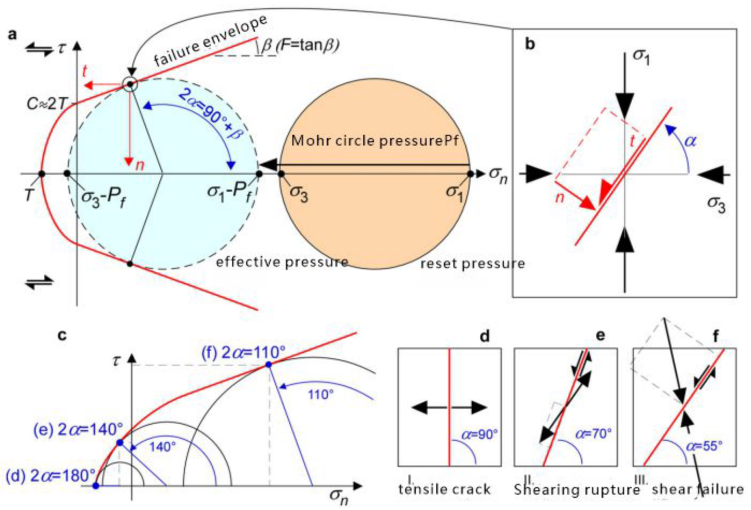

Figure 5: Left shift of fluid pressurized Mohr circle

When the fluid migrates upward through the pores, the vertical gradient of overpressure will produce seepage force, which acts vertically on each particle of the rock. On the diagram of the relationship between shear stress and normal stress (Fig.5), with the increase of overpressure, the Mohr circle representing the stress state gradually moves to the origin. However, its size will also decrease. When the fluid pressure compensates for the weight of the covering layer, the effective stress in the solid frame disappears completely. If the overpressure exceeds the weight of the overburden, the vertical effective stress becomes tensile stress, and the rock may eventually be destroyed under tensile stress, resulting in horizontal cracks. If there are additional tectonic stresses, their complex effects may lead to vertical tensile fractures or shear fractures.

1.2. The genetic mechanism of cone structure

These hypotheses (in addition to the origin of paleontological fossils) proposed for the mechanism of the cone of the cone structure in the formation of the cone structure can be combined into four explanations related to the following processes : (1) rock static pressure and dissolution, (2) gas emission, (3) crystallization, (4) deposition. The cone-in-cone structure was first mentioned in the literature in 1793, which attracted the attention of geologists because of its highly ordered arrangement. In the early 19th century, some researchers suggested that the conic structure was an ancient fossil known as Cophinus dubius (Twenhofel, 1932). This structure has been found in different sedimentary rocks in almost all parts of the world, from Riphean to Cretaceous. In 1859, H. Sorby made a report on the hypothesis of crystallization. Under certain conditions, minerals can crystallize in a fibrous form around certain crystal axes in sediments. It was later modified by G. Kohl and proposed that the cone was composed of clay minerals extruded from the sediment during the crystallization of fibrous calcite. In 1922, Tarr proposed that pressure and CO_2 were the main reasons for the uneven dissolution of calcite, but there was no advanced technology to show the characteristics of age difference at that time. Before Tarr, scholars believed that the cone structure initially had nepheline composition, which was caused by pressure during the nepheline-calcite transition process and thus crystallized. However, Tarr did not observe the aragonite cone, so it was questioned. In 1948, Shvetsov proved Tarr 's view that calcite was replaced by silica in the lower Carboniferous rock cones in the Moscow area. In 1965, Kanskii proved that it was a calcite crystal after aragonite when he studied the cone structure in the Upper Jurassic rocks in the Donetsk Basin. Based on the study of the spatial relationship between the cone-in-cone structure and the early diagenetic nodules, Frolov concluded that the cone-in-cone structure was formed in the early diagenesis stage. At the same time, he also emphasized that many aspects of the formation mechanism of the cone-in-cone structure are still unclear. Matveev, on the contrary to Sorby, believed that the pyramid structure is a complex crystal formed by ' interfering with the crystal field in some way under the influence of fossil life ' (Matveev, 1948).He is also one of the earliest researchers to remind scholars of the possibility of using the pyramid structure as a guide for the exploration of certain types of deposits. Shaub discovered and described cone-shaped funnels in loose sediments formed after flood recession. He proposed that the cone-shaped structure was the result of the gradual decline of the basin water level, and the dehydration, contraction and sedimentation of the sediments produced cone cups. Oreshnikova suggested that regional structure and sedimentary facies should be considered in the study of conical structure.

During the Second World War and shortly before and after it, the description of the cone structure of France, Belgium, and their respective colonies in Africa (Morocco, Algeria, Madagascar, and Belarus) appeared in the French literature, which triggered a debate about the cone formation mechanism (Denaeyer, 1943) and scholars compared the French cone structure with the British cone or beef. Since then, there have been many reports of cones in fibrous vein cones around the world and further discussions on possible formation mechanisms. Nalivkin believes that the cone-in-cone structure has the properties of multiple mechanisms. In each specific case, it can be formed by any of the above mechanisms, including the biogenetic mechanism. In the past decade, Bons and Montenari et al.observed the anti-axis fibrous veins of Oppaminda Creek under scanning electron microscopy and found that the calcite fibers were embedded in an unusual spherical structure of about 1mm.They interpreted these spherical structures as microbial fossils living in pore space during the formation of veins [3]. Fluid inclusions and burial history suggest that these veins were formed at temperatures well below 100 °C in the late Proterozoic. Whether the existence of microbial life promotes the precipitation of calcite to some extent, and whether the growth mechanism of anti-axial veins is related to it is still an open question.

The conic structure formed in the early diagenetic stage is considered by some scholars to be an aragonite crystal fan (Kristin D et al, 2013). Modern aragonite fans are commonly found in carbonate rocks and reef cavity fillers or as submarine crust. The aragonite crystal fan is a fan-shaped aggregate of acicular aragonite, which is usually called primary seabed sediment. As an authigenic carbonate precipitate, it can provide important information on marine chemical evolution. The structure of its type is recorded in Archean-Proterozoic. However, no early diagenetic aragonite fan has been found in siliceous sediments in modern environmental or geological literature. For the explanation of the genesis of aragonite crystal fans, relevant scholars believe that it has an important relationship with the changes of marine environment during the mass extinction period by studying the stratigraphic age characteristics of its distribution. In recent years, relevant scholars have proposed that seawater acidification during the mass extinction period is also an important reason for the formation of cone structure. Schaller et al.proposed that volcanic eruptions rapidly inject large amounts of carbon dioxide into the atmosphere (Schoene B et al., 2010), which may lead to ocean acidification. He proposed that if the peak duration of carbon dioxide gas emission is very short, the gas volume of volcanic eruptions may be sufficient to make the carbonate content on the ocean surface too low. Greene et al.believed that seawater acidification led to an increase in total dissolved inorganic carbon (Greene et al., 2012), that is, an under-understood carbonate sink throughout the T-J transition stage, resulting in a strong degradation of fibrous calcite at the bottom redox boundary at the end of the Triassic. Heindel et al. (Heindel et al., 2015) also used seawater acidification for coning under the extinction event of the Permian-Triassic boundary (Heindel et al., 2015). They believe that the early Triassic seabed appears to be a carbon sink, and the formation of microbially induced secondary diagenetic carbonate rocks. These studies have mentioned that this cone-in-cone structure is formed in the shallow seabed, formed at the same time as the deposition, is the product of the early diagenesis stage, and is the reaction of large-scale volcanic eruption leading to carbon dioxide into the atmosphere ; carbon dioxide is transferred to the ocean, resulting in seawater acidification, which leads to carbonate deposition. Greene et al.and Heindel et al.studied the cones during the Permian-Triassic extinction period and believed that these fibrous calcite layers represent the early cementation of extremely shallow burials in the marine environment related to the mass extinction. A large number of studies have shown that there is a lack of abundant precipitated carbonate fans in the microbialite of the Permian-Triassic boundary (Hautmann, 2004), including reef gap and carbonate facies (Wang, 2023), biology, sedimentology (Kiessling et al., 2009) and geochemical extinction (Grice et al., 2005). Therefore, in recent years, some scholars have also questioned the study of aragonite crystalline fans. However, there are abundant early diagenetic nodules in the same strata in some areas, indicating that there may be diagenetic events of carbonate deposition at the T-J boundary. Although T-J ocean acidification remains controversial, although the T-J boundary segment is not a global anoxic event, local hypoxia may promote the deposition of early diagenetic carbonates by limiting the dissolution of carbon dioxide caused by oxygen respiration and remineralization through hypoxia. The ocean acidification hypothesis provides a possible explanation framework for carbonate rocks that explain the rich early diagenesis process. In order to better understand the formation mechanism and environmental significance of the aragonite crystalline fan, we also need to record and analyze these submarine precipitation in the whole geological history. In addition, the microbial processes, microbial populations and microbial ecology of the main diagenetic pathways under different sedimentary environments were studied by using geochemical principles and geological microbiology methods (Zhang Yanping, 2017), which is also the basis for further study of the mechanism of early diagenesis and other submarine biogeochemical processes (Zheng Min, 2023).

4. The growth mechanism of vein

The mechanism of vein growth can be divided into two categories : (1) vein formation dominated by advection fluid (Robert and Brown, 1986 ; mcCaig et al. 1995) ; (2) Vein formation dominated by diffusion transport (Durney and Ramsay, 1973 ; durney, 1976 ; ramsay and Huber, 1983 ; late, 1983 ; fisher and Brantley, 1992 ; jamtveit and Yardley, 1997 ; oliver and Bons, 2001).

In the first type of vein growth mechanism, nutrients can be transported to the vein growth site over a long distance. Such a vein growth system can be classified as ' open ', so it should be noted that ' open ' or ' closed ' depends on the size of the vein growth system considered. Many processes can lead to the actual precipitation of transport nutrients, such as temperature changes (Eisenlohr et al., 1989), pressure changes (Vrolijk, 1987 ; henderson and McCaig, 1996), reaction of surrounding rock with fluid mixing (Boullier et al., 1994).

The second type, diffusion transport, is usually related to vein growth in closed systems because the distance of diffusion transport is limited : usually limited to the centimeter-centimeter level. Vein-like precipitation from diffusely transported nutrients may be caused by differences in porosity (Putnis et al., 1995) or differences in pressure gradients, and is generally considered to be associated with dissolution-precipitation creep deformation, such as the common close connection between columnar rocks and veins (Beach, 1974) ; durney 976 ; mullenax and Gray, 1984).

5. The origin of fiber veins and cone-in-cone structure is controversial.

Beef veins and cone-shaped structures exist in both marine and non-marine sediments, so ocean action is not a necessary condition for their formation, and some scholars attribute the cause of cone-shaped structures to changes in the marine environment. Whether the cone structure was formed in the early or late diagenesis is still controversial. A widely accepted genetic explanation is that Cobbold et al., mentioned in 2013 that they were formed under deep buried high pressure and high temperature, which has been used as evidence of tectonic belt stress by Le Breton et al. (Le Breton et al., 2013). Tapered cones and beef may also be related to oil and gas generation and migration. In other words, in the late stage of diagenesis, cones and beef structures are also important for the formation of oil and gas reservoirs. These fibrous calcites grow on existing limestone nodules. For example, Marshall 's evidence includes growth on nodules (Marshall and Astini, 1997), such as the Lower Jurassic birchii nodules in southern England reported by Hesselbo and Jenkyns. As well as the famous website Ian West 's photos are very good description of its late diagenesis stage of the nodules. Kristind 's explanation is different because they suggest that cones may also have been formed during early diagenesis near the sediment-water interface. Kristind 's sediment-water interface model is based on the combined effects of the main microbial respiration pathways in modern marine basins and the dual effects of biological disturbances. It is found that these unsaturated environments promote the dissolution of aragonite, which is similar to shallow sediments in modern oceans. It is the result of bacteria-mediated sulfate reduction, which may be related to sulfate-dependent anaerobic oxidation of methane. Some authors emphasize that the conic structure is caused by conical shear fractures, which is suitable for both early diagenesis and late burial. This means that even under shallow burial conditions, there must be vertical restrictions. In the presence of ascending circulating fluids or shallowly buried sealed environments, vertical restrictions may be bottom-up. The correlation between the formation of the pyramid structure and the BSR and TSR processes (Worden et al., 2000) depends on the change of the formation temperature. Whether there is an inevitable connection between its causes and environmental changes during the mass extinction period is also a controversial issue for many scholars. In the early diagenesis stage, many scholars believed that the formation of cones was closely related to the environmental changes during the mass extinction. Stephen Kershaw found that most of the crystals in beef veins and cones grew uniformly upward and downward, that is, they preferentially grew upward in soft sediments. They found that the calcite structure in cones was widely distributed geographically and stratigraphically, rather than gathered in the mass extinction (Kershaw et al., 2016). It is believed that cone growth has nothing to do with the mass extinction, and some scholars have proved that it has nothing to do with the mass extinction with the examples of early Jurassic and early Cretaceous. In addition, the U.S. Death Valley rainstorm segment studied by SaraBradyPruss currently contains the youngest known aragonite crystal fan in the Proterozoic (Pruss et al, 2008). A better understanding of the formation mechanism of aragonite crystal fans in this young stratum is of great significance for the formation of carbonate fans in this period and other abnormal periods in the history of the earth.

In recent years, there have been more and more debates on the mechanism of dike formation. The focus of the debate is on whether there is the necessity of cavity formation before the growth of dikes, and whether the dikes record the mass transfer of advection or diffusion in the crust. The morphology of different vein textures (such as fibrous, slender block, crack-like, stretched crystal, block) changes with the opening of the vein, and the crystal growth kinetics changes. Some previous researchers have proposed that some textures (such as fiber textures) are related to diffusion mass transfer, while other textures (such as blocks) are related to advection state.

Some recent studies have also shown that veins can also be formed without rupture, and the growth of veins is driven by the diffusion and transport of material directly to the surrounding rock. The anti-axial stretching pulse may be formed without rupture, rather than through the commonly known crack-sealing mechanism. It has also been suggested that these veins may obtain local nutrition through diffusion transport. This hypothesis was tested by Elburg et al. (2001) in the carbonaceous shale of Oppaminda Creek in the northern Flinders Mountains, South Australia.

Meng et al.showed through lithofacies observation that the cementation of natural fractures in low-permeability rocks depends largely on the presence of nodule minerals in host rocks. In the stratum of evaporite, the development of gypsum fiber veins is closely related to the disseminated gypsum nodules in marl. According to the stratigraphic correlation, the material of gypsum fiber veins in marl is derived from the disseminated gypsum cement in the surrounding rock (Meng et al., 2017), and its Sr concentration is much lower than that of gypsum nodules. Therefore, Meng believes that gypsum is mainly transported to adjacent veins through diffusion in low-permeability marl.

Although the origin of the anti-axial tensile vein has not been clearly stated, there is a significant difference in the microstructure of the anti-axial tensile vein in the shale and coarse-grained carbonate formations (Bons and Montenari, 2005). The growth of the veins in the shale formation shows good ductility, while the veins in the coarse-grained carbonate formations show repeated fracturing growth. Bons believes that the supersaturation level affects the growth rate of the veins, resulting in this difference. Some scholars believe that the formation mechanism of anti-axial stretching veins is mainly closely related to fluid overpressure.

6. Conclusions

Beef veins and cone-in-cone structures have different genetic conditions under different stratigraphic conditions, which are closely related to the sedimentary conditions of the strata. For the study of beef veins and cones in shale and mudstone, scholars have carried out a large number of hydraulic fracturing experiments and mechanical analysis. It is believed that it is mainly related to the fluid pressure of the rock formation, and the fluid pressure is also an important condition for oil and gas storage, which plays an important role in the development and utilization of oil and gas. For the beef veins and cone-in-cone structures in carbonate rocks, the genetic mechanism of some carbonate rocks after the great extinction period is still unclear. However, scholars have proposed that it is due to the effect of seawater acidification during the mass extinction period on the early diagenesis stage of carbonate rocks. Therefore, the study of cone-in-cone and beef veins in carbonate rocks is of great significance for restoring the ancient marine environment at that time.

The study of microorganisms in the pulse also shows us a new perspective and research direction. What is the role of microorganisms in the formation of veins Do they play a passive role only because of the pore space and chemical environment during the formation of veins Or do they actively participate in the precipitation of calcite, thus forming a microbial-assisted rock deformation These aspects are all issues that we should study.

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