地热流体

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[内容提要] 地热流体是沉积岩孔隙空间中的流体，这里提出的地热流体这一术语，是用来描述通过地球中孔隙空间的流体。本文讨论了地面和大气水流、压实流、对流和孔隙流体。

关键词 地热流体 压实流 对流 孔隙流体

GEOFLUIDS

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ABSTRACT

Geofluids are fluids through pore spaces in the sedimentary rocks. This paper presents a discussion of geofluids as a term which has been used to describe the fluids through pore spaces in the Earth. Ground and meteoric water flow, compactional flow, convection current and pore fluids have been discussed in this paper.

Key words: geofluid, compactional flow, convection current, pore fluid

INTRODUCTION

since geofluids viewed as any fluids occupying and moving through pore spaces in sediments, we don't need to say "BASIN GEOFLUIDS" or "GEOFLUIDS IN SEDIMENTARY BASIN" because we think the term "GEOFLUIDS" which was used for the first time in May, 1993 at Torquay for the "GEOFLUIDS, 93" conference, has a full meaning whereas we know that "GEO" means the Earth and "FLUIDS" are any substance in a liquid or a gaseous state. So a liquid or gas which moves through the rocks in the Earth's subsurface

can be explained in the term of GEOFLUIDS. But that when we speak about fluids moving in the Earth in general. If we want to talk specifically about the fluids in some where in the Earth, we need to mention a kind of the rock or a type of structure which contains these fluids in the subsurface of the Earth, such as GEOFLUIDS IN SEDIMENTARY ROCKS or BASIN GEOFLUIDS etc.

DISCUSSION

In general geofluids can be magma, water or hydrocarbon materials. Water is most effective fluid within the sedimentary rocks and sedimentary basins, and this is because it is widely present in the sedimentary rocks.

For many processes in aqueous systems, the details of the molecular structure of water may be safely ignored. However when dealing with dimensions in the range from colloidal particles to molecular dimensions (1μ-Å) it becomes necessary to pay careful attention to structural aspects of aqueous environment. Thus when dealing with the sedimentation of clays and other minerals as well as when describing fine-grained sediments, both bulk and interfacial water structures play a role (W. Drost-Hasen, 1991). Pore water flow in sedimentary basins is a very important parameter in diagenetic processes. It is necessary to consider the chemistry of the fluids which move through the pores and their effect on cementation and dissolution. Geofluids have the capacity to enter into chemical reactions with solid components.

Burial diagenesis results in mineralogical evolution that is frequently correlated with variations in physical and chemical conditions as a function of increased depth. These variations are the finger points of fluid-migration-related mass transfers with release and input of chemical elements during mineral transformations, precipitation or dissolution or dissolution-chemical and isotopic studies of formation waters might, therefore, be very useful to address the physical conditions of the latest or even the on-going diagenetic episode in sedimentary basins (S. Furlan et al., 1995).

In the Earth crust the temperature is largely controlled by heat conduction. However under some circumstances, the thermal state is disturbed by advection of heat associated with ground water flow. The corresponding thermal distribution depends on the water flow velocity, and therefore thermal data may be used to constrain the convection. They are based on the assumption that the water flow is concentrated in thin permeable structure such as aquifer or fault zone.

Fluid flow in sedimentary basins may transport heat, cause dissolution and precipitation of mineral phases and influence petroleum migration and emplacement. Three mecha-

nisms for pore water flow are generally recognised (Bjφrlykke et al. ,1988;Bethke,1985, 1989);(1)Pore water driven by a hydraulic head above sea level;(2)Pore water driven by compaction of sediments during burial and (3)Rayleigh and non-Rayleigh convection of pore water caused by density variations.

Ground and meteoric water flow

It was found that it is not easy to quantify meteoric water flow rates in a sedimentary basin. However pore water in sedimentary basin is driven by fluid potential gradients (Dahlerg,1982) and there are several different types of driving forces for such flow:

(1)Mechanical compaction due to overburden;

(2)Density's difference result from the difference of temperature and salinity;

(3)Ground water head above sea level,this type of flow will drive meteoric water into the basin,particularly in confined aquifers,and try to establish an isostatic equilibrium between meteoric and more saline connate pore water (K. Bjφrlykke et al. ,1988);

(4)Formation of hydrocarbon materials make displacement for water when the pressure build up in a source rock;

(5)Dehydration as a result of some mineral reactions.

Sedimentary basins are heterogeneous and filled with sediments,they have different permeability. Therefore the flow of compaction driven water is very complex and tend to be focused through permeable sediments. However taken as an average for the whole basin, the above generalisations are true (K. Bjφrlykke et. al. ,1988).

Open fractures provide high-permeability pathways for fluids in sedimentary basins. The potential for flow along permeable or open fractures and faults depends on the continuity of flow all the way to the surface except in the case of convective flow. Upward flowing fluid cools and may cause cementation due to the prograde solubility of quartz,but in the case of carbonates such flow may cause dissolution. The rate and duration of these processes depend on the mechanisms for sustaining fluid flow into the fracture,the geometry of fracture and sedimentary bed intersected,permeability,pressure and temperature gradients.

When pore water flows through the fracture it carries heat upwards. It loses some of this heat to the adjacent sediments,causing a reduction in its temperature and an increase in the temperature of surrounding sediments. Heat is lost from the flowing fluid vertically as well as horizontally. As we assume that there is no fluid transport normal to the walls of the fracture the lateral heat flow through the walls takes place by conduction only. In the fracture,however,heat transport occurs by both advection and conduction.

Hydrodynamic flow is important as a mechanism for cementing secondary sandstone porosity in weathering zones that may ultimately be preserved beneath unconformity (Rechard C. Selley, 1988). It sometimes traps petroleum in textures that true closure (therefore termed hydrodynamic traps), (Dahlberg, 1982)

COMPACTIONAL FLOW

Sediment compaction has the effect of decreasing porosity and in absence of equilibrating fluid flow, raising fluid pressure.

When sediments are deposited, they have a high water content and the sediment grains are packed in an unstable manner. As the overburden increases the stress on the grain contacts increases and the framework of the sediment grain compacts. When the packed framework of grains which was formed during deposition is destroyed, the grains became compact and packed more closely together. For this to be able to happen, however water must flow out of the bed as the porosity decreases, this leads to an upward flow of pore water and fine sediment. If we measure the pressure in the pore water, we will find that it increases during compaction when the unstable grain framework is destroyed. The conventional view is that excess pore water is squeezed out of the compacting sediment as the overburden pressure increases during burial. Van Elsberg (1978) pointed out that this only is a partially correct view. Considered on a basin wide scale, what really happens is not that the water moves but the sediment continues to sink through the pore fluids. And we can add to this view that as sediments sink through the pore fluids, and force the fluid to leave the place for it. So ultimately water movement is happened.

CONVECTIVE CURRENTS

Convection currents are important processes in nature. They generate thunder storms in the atmosphere and in the mantle, and are believed to be responsible for continental drift.

The fluid motion is considered here as a type of thermal convection referred to Raleigh convection. It arises where a fluid contained between two horizontal plates is heated below and cooled above. The basic driving force is the slight density difference in the warmer fluid at the bottom in relation to the cooler fluid at the top. However, fluid movement does not necessarily result in major diagenetic observation. To explain many diagenetic observations it is necessary to show that sufficient solid mass can be transported from point to point in responsible geologic times. K. Bjφrlykke(1988)from his calculations and modelling has got to that thermal convection probably does not play an important role in the transport of

solids in solution in sedimentary basins under normal conditions but may be important areas where there are high lateral variations in temperatures(sloping isotherms).

If thermal convection occurs in rocks under conditions of chemical equilibrium, it follows that mass transfer of the matrix phases have temperature-dependent solubility and fluid equilibrium is maintained(F. J. Long, 1984).

PORE FLUIDS

Pore fluids have a great influence within sandstone formation throughout chemical reaction which occur for the minerals of sediments after deposition.

If K-feldspars originally constitute about 10% by volume of the sand fraction of Friosandstone(5% of the volume of the sandstone assuming 5% initial porosity), then the most likely dissolution reaction can be written as an equation:

$$2KAl\,Si_3O_8 + 2CO_2 + 7H_2O \rightarrow 2K^+ + Al_2Si_2O_5(OH)_4 + 4H_4SiO_4 + 2HCO_3^-$$

If K-feldspars constituted approximately 5% of the original volume of the sands, then 0. 05 cm^3 = 0. 46 millimoles of K-feldspar have been regionally destroyed in each cm^3 below about 12500 ft in Frio sandstone. An equal number of moles of CO_2 were consumed, and K^+ and HCO_3^- released(L. S. Land, 1979).

According to the above stoichiometry, about 0. 46 millimoles of K^+ are released by destruction of K-feldspar for each average cubic centimetre of Frio sandstone below about 10^2 millimoles of K^+ per cm^3. Present—day pore fluids in Frio sandstone average about 5×10^2 millimoles K^+ cm^3 and only very rarely exceed 1.2×10^2 millimoles per cm^3 fluid. Since no significant potassium deposited in the sandstone can be identified, potassium must be transported out of the sandstone. If advective transport is involved, and if potassium contents only twice that of sea water are allowed then 1. 5 millimoles.

We should know that pore water of most modern sands are either fresh or similar in composition to river waters. In contrast, the pore water of ancient sandstone may vary from potable water aquifers near the surface, not too dissimilar from the river water compositional range, to the concentrated brines contained much more Ca^{++} ions, and the reverse is true for sea water. Like water of many evaporate lakes, formation waters may be enriched in sulphate, bicarbonate, or chloride ions. Silica is usually increased. All of these changes are evidence of chemical reactions that have taken place between pore fluids and rocks after deposition. Oil and gas and other hydrocarbons derivatives can not be found in modern sand, while ancient sandstone in many regions over the world contain all kinds of hydrocarbons.

Petroleum fluids are distributed throughout a sedimentary basin as a cumulative re-

sponse to the complex, dynamic interplay of geological, physical and chemical processes.

Table 1 A synthesis of nomenclature describing geofluids

Adopted grouping	Subgruop	Sub-subgroups	Other groupings		Comments
	Formation water	Pore water Diagenetic water	Interstitial water products of diagenesis	Oil field brines. connate waters petroleum	Trapped during sedimentation e.g. from clay dehydration both bio- or thermogenic methane recognised thermally degrades to solid and gas
Internal fluids	Hydrocarbons	gas Oil 'Solid' bitumen		'Plastic solids'	once fluid/plastic flow e.g. salt or shale behaving as fluid
	'Fluid' rocks Authropogenic		Surface water		e.g. Drinking water, effluent contains dissolved air and bacteria
	Meteoric or artesian water	precipitation Tectonically uplifted water	Hydrothermal		Pore water Lakes etc.
External Fluids	metamorphic	Water Gases			from dehydration reactions e.g. H_2 CH_4, CO_2, H_2O (dissolved)
Mantle		Water Methane	Primordial		Often chemical reactive Never known to be commercial

If a fluid is defined as 'that which flows', then heat and energy might appear in this table. Connate water is defined as 'water' that has not been exposed to the atmosphere since "deposition". Pore water is sometimes called 'interstitial water', which can include diagenetic contributions (S. R. Lawrence and C. Comford, 1995)

SUMMARY

Geofluids are any fluids moving through rocks in the Earth's subsurface. First of all we think that, the term 'GEOFLUIDS' is good enough to describe the fluids in the Earth which are in constant reaction with the components of the Earth, making a noticeable remarks on the rocks, playing a major role in chemical and physical processes which have taken place in the natural rocks's processing.

Geofluids are an important parameter in diagenesis processes and scdimentary basin evolution.

In this paper we have concentrated our discussion on ground and meteoric water flow, compactional flow, convective motion and pore fluids.

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