PRJ, Vol. 6 (January 1994); P. 75–84, 11 FIGS, 1 TABLE.

RESERVOIR QUALITY ANALYSIS - AN OVERVIEW WITH EXAMPLES FROM THE SIRT BASIN

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تحليل جودة المكمن : نظرة عابرة مع أمثلة من حوض سرت

ر. سي. ثوم

يمكن تعريف جودة المكمن كتقدير كيفي لقابلية أي صخر لإنتاج الموائع ، التي تعتبر المواد الهيدروكربونية أفضلها. وعادة ما يتم تحديدها باستعمال وسائل الشرائح المجهرية الرقيقة والمجهر الإلكتروني الفاحص (SEM) والأشعة السينية المنكسرة (XRD).

تشمل المشاكل المرتقبة التي قد تؤثر على جودة المكمن ، هجرة الرواسب الدقيقة (الحجر الرملي بحقل المسلة) والحساسية للأحماض (تكوين خليفة) وإنتفاخ الطفلة.

ومن المهم تحديد نوع وكمية المعادن التي تهديدها قائم ، كذلك مواقع وأشكال هذه المواد بالنسبة لنظم الفجوات. هذا بالإضافة إلى أهمية المسامية والنفاذية بالنسبة لوجود المكمن. وعموماً ، فإن جيولوجي الإستكشاف والتطوير يستعملون المسامية المستمدة من تحاليل السرود ولبب الآبار (أي المسامية الكلية). وفي كثير من المكامن ، يتألف قسط مهم للفراغات من فراغات معزولة لا تساهم بشيء للنفاذية (تكويني خليفة وزلطن) إذا من المهم تحديد نسبة المسامية المؤثرة ألى المسامية غير المؤثرة.

يمكن إعتبار دشيش الحفر عينة مباشرة حول مكمن محتمل ولكن المعلومات المستمدة من هذه المواد لا تعتبر عادة ضمن العوامل التي تحدد استكمال البئر من عدمه. ويمكن الحصول أيضاً على معظم معلومات جودة المكمن المستمدة من عينات لبب الصخر، ومن فحص دشيش الحفر في الشرائح الرقيقة مجهرياً وباستعمال المجهر الألكتروني الفاحص ومن أمثلة ذلك الهيكل المعدني ، المجموعات المعدنية المتحورة ، وأنواع الفراغات (المسام) وهكذا.. في كثير من الحالات يمكن الحصول على النفاذية ومسامية تحليل لب الصخور بطريقة حسابية من فحص دشيش الحفر.

وقد تم توضيح تقنيات الفحص المجهري للصخور في تحديد جودة المكمن باستعمال أمثلة من تكوين خليفة وتكوين زلطن علاوة على الحجر الرملي بحقل المسلة.

ABSTRACT

Reservoir Quality can be defined as a qualitative estimate of a rock's ability to produce fluid, preferably hydrocarbon. It is generally determined using thin section petrography, scanning electron microscopy (SEM) and X-ray diffraction (XRD) techniques.

Potential problems which may affect reservoir quality include fines migration (Messla Field Santstone), acid sensitivity (Khalifa Formation) and swelling clays. The type and quantity of potentially damaging minerals, plus the position and morphology of this material with respect to the pore system is significant. In addition, porosity and permeability are obviously important with respect to reservoir quality. In general, exploration and development geologists use log and core analysis derived porosity (i.e. total porosity). In many reservoirs a significant proportion of the pore system consists of isolated pores which do not contribute to permeability (Khalifa and Zelten Formations). It is important to determine the proportion of effective vs non-effective porosity.

Drill cuttings can be small pieces of a prospective reservoir, though the information available from this material is not often incorporated into completion

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decisions. Most reservoir quality information that can be obtained from core samples can also be obtained from thin section and SEM examination of drill cuttings, for example, framework mineralogy, diagenetic mineral suite, pore types, etc. In many cases, permeability and core analysis porosity can be empirically derived from cuttings.

The use of petrographic techniques in the determination of reservoir quality is illustrated using examples from the Khalifa and Zelten Formations plus the Messla Field Sandstone.

INTRODUCTION

Reservoir Quality and fluid sensitivity can be determined using a combination of thin section petrography, scanning electron microscopy (SEM) and X-ray diffraction (XRD) techniques (AGAT Laboratories, 1983).

Thin section petrography (core, drill cuttings, outcrop or sidewall plug samples) generally forms the basis of any reservoir quality study (Fig. 1), providing information on primary mineralogy (framework and matrix composition), diagenesis and pore types. This technique is also useful for determining the position of potentially reactive minerals with respect to the pore system (i.e. authigenic kaolinite within pores is far more likely to contribute to a fines problem than detrital kaolinite within argillaceous rock fragments).

Standard thin section petrography involves two dimensional examination of the sample under magnifications of 25 × to 400 ×. In some cases, it is not possible to distinguish clays, fines or precipitates in the pore system and scanning electron microscopy (SEM) may be necessary.

SEM's are capable of magnifications between approximately 10 × and 100,000 ×, while maintaining a great depth of field; thus, scanning electron microscopy provides high magnification three-dimensional views of the rock, which can be used to supplement or enhance information derived from thin sections. SEM samples generally consist of a 1 centimetre sample of freshly broken core or drill cuttings.

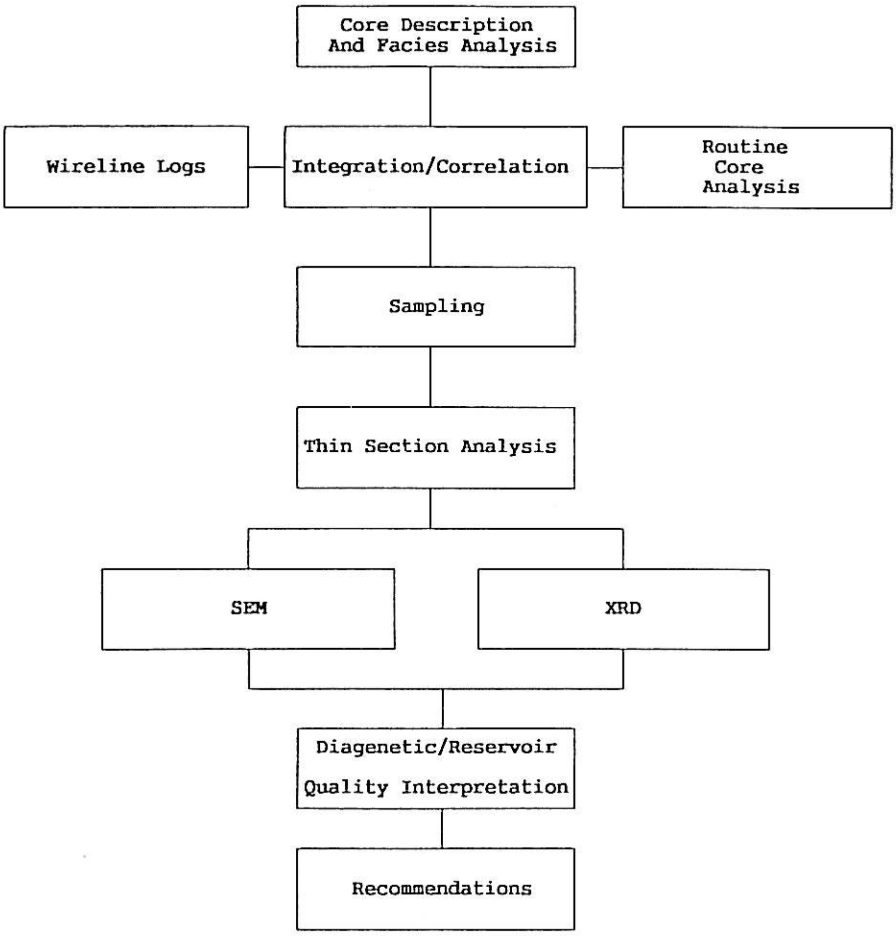

FIG. 1. Generalized flowchart of the reservoir quality analysis process.

SEM examination is particularly useful for the determination of pore and pore throat morphology, as well as the identification and distribution of clays and other fines in the pore system.

Most SEM's have an attached dispersive X-ray energy spectrometer (XES) which can be used to help identify minerals by determining the elemental composition. This instrument can be used to determine the elemental makeup at a single point (i.e. to look at zonal variations within a single grain) or within a selected area (incorporating more than one grain or crystal).

X-ray diffraction (XRD) is another analytical tool used to complement thin section petrography, XRD can determine the type and approximate abundance of minerals in a powdered rock sample, and is particularly good at clay identification. This technique is based on the characteristic reflection of X-rays by crystal lattice planes within minerals. Each mineral has diagnostic X-ray pattern with known peak locations and intensities. Amorphous (non-crystalline) material (e.g. bitumen) will not diffract X-rays and will not be identified by X-ray diffraction analysis.

Both bulk and clay-fraction XRD analyses are normally run on a rock sample. The bulk analysis is performed on the entire powdered sample to provide the relative mineral percentages. In a clay-fraction analysis the clays are concentrated by separating the less than 4 micron size fraction (using centrifuge and decanting techniques) from the bulk sample. This concentration of clays is necessary because these potentially reactive minerals are often present in small amounts and their presence would be masked by the abundance of other minerals in a bulk sample. Clay-fraction samples are commonly glycolated (to identify swelling clays), heated and/or acid washed (to distinguish between kaolinite and chlorite).

XRD is very useful for identification of minerals, particularly clays; however, the position of these minerals with respect to the pore system cannot be determined by this technique. In addition, XRD analysis cannot distinguish between minerals with the same composition (e.g. monocrystalline quartz, chert and silica within rock fragments will all show as quartz).

A comparison of the benefits and limitations of thin section petrography, SEM and XRD techniques is provided in Table 1. It is important to realize that only a small portion of the reservoir is being examined and that the selection of representative samples is critical.

FINES MIGRATION

Permeability reduction as a result of migration of formation fines, can be significant when drilling, completing and/or producing a reservoir (Gabriel and Inamdar, 1988). Loosely attached fines (detrital clays, authigenic kaolinite, authigenic illite, silicate fines-disaggregation of lithic clasts, carbonate fines-dolomite, siderite, calcite) may be mobilized and move from the interior of pores and/or pore walls to collect at pore throats, thus reducing permeability.

Table 1. Comparison of Petrological Techniques

Equipment	Uses/Benefits	Limitations
Polarized Microscope	– mineralogy – types and quantity – framework grains – matrix – cements, some clays – porosity/permeability controls – diagenetic modifications – grain size determination	– upper limit mágnification ×400 – two-dimensional – can't identify fine matrix/clay minerals – thin sections take at least 1 day to prepare
Epi-Fluorescent Microscopy	– porosity distribution – fracture/matrix/vug relationships – effective porosity – microfractures	– same as polarizing microscope – best for carbonates – requires fluorescent dye
X-ray Diffraction	– rapid analysis of mineralogy – bulk sample, whole rock – clays in clay fraction	– semi-quantitative – accuracy dependent on mineral crystallinity – no information on mineral distribution
Scanning Electron Microscopy	– detailed examination of pore system – high magnification – mineral identificaton with XES system – use in conjuction with displacement tests – metallurgical samples	– small sample may not be representative

The following points have been stated regarding fines migration:

- Migration will only occur if the phase that wets the fines is mobile, i.e. in a water-wet zone producing oil or gas, fines migration will only occur when water is produced (Muecke, 1979).
- The relationship between the sizes of pore throats and fines is another factor affecting the degree of permeability reduction as a result of fines migration. Fines can collect at pore throats if their diameter is 1/3 or more of the throat diameter.
- The fluid production (or injection) rate at which significant fines migration initiates permeability reduction is termed the "critical velocity". Critical velocity is not attained when only the non-wetting phase is flowing, indicating the importance of wettability. It has been determined that fines are mobilized even at subcritical velocities, but that pore throats are not blocked in sufficient quantities to create significant permeability reduction.
- Authigenic kaolinite migrates as "booklets" rather than as individual platelets and authigenic illite can act as "fishnets" to catch mobile fines (Porter, 1989).
- Selby *et al.* (1988) showed that fines flow in porous media was influenced by:
  (i) the initial amount of fines
  (ii) the fluid flow rate
  (iii) the size and shape of the framework grains
  (iv) the size and density of the fines
  (v) the overburden pressure
- Migration can occur if the salinity of injection water is lower than formation water, or if the divalent ion concentration is reduced or replaced by monovalent ions (Gray and Rex, 1966). Changes in pH can promote migration and gradual changes in the salinity of injection water tend to minimize migration (as compared to significant migration if the zone is "shocked" with water of very different salinity to the formation brine).

Thin section petrography can be a useful "first step" in the identification of formation fines. SEM examination is often used to determine the type and distribution of fines plus the size of fines in relation to pore throats. XRD analysis is used for identification of clay types and, in conjunction with thin section work, gives an approximate abundance of clays.

Following the identification of a potential fines migration problem, core flow tests at reservoir conditions of temperature and pressure, can determine the degree of permeability reduction at different interstitial fluid velocities (Fig. 2a). The effect of water composition on fines migration and the "critical velocity" may also be determined in flow tests.

If production and injection rates are below the "critical velocity" then significant permeability reduction as a result of fines migration is not expected. In cases where it is not feasible to keep interstitial flow velocities below the "critical velocity", and where significant fines migration has already damaged a zone, a fracture stimulation will provide large flow paths and reduce near wellbore interstitial flowing velocities (thus minimizing potential fines migration) (Economides and Nolte, 1989).

Clay stabilizers have been used to prevent mobilization of clay fines (Sydansk, 1983). These stabilizing agents coat the surface of the clay particles and prevent them from "seeing" salinity changes during waterflooding or steamflooding. Hydroxyaluminum, polyacrylamides, asphaltenes and polyvinyl alcohol solutions have been used as stabilizers. Core flow tests at numerous laboratories suggest that many commercially available clay stabilizers cause more damage as a result of reduced pore volumes than fines migration would have caused in an untreated rock.

The Messla Field Sandstones are very fine to medium grained, moderately well sorted sublitharenites with significant proportions of authigenic kaolinite (Fig. 2b). This diagenetic clay has precipitated within the pore system and appears to be migratable to pore throat blocking positions.

ACID SENSITIVITY

Using acid in completion and stimulation can result in formation damage as a consequence of one or more of the following factors:

(i) precipitation of iron hydroxide gels
(ii) precipitation of fluoride and silicate gels
(iii) release of fines
(iv) fabric collapse
(v) creation of emulsions or "sludge"

(i) Reactions between spending treatment acid (either during a matrix acid squeeze or an acid fracture stimulation) and iron-bearing minerals can result in the precipitation of permeability-reducing iron hydroxide gels. Iron within the crystal lattice of these minerals (chlorite, siderite, ferroan carbonate, hematite) goes into solution and may subsequently precipitate as the acid spends; ferric (Fe^{3+}) iron precipitates when the pH exceeds 2.2, whereas ferrous (Fe^{2+}) iron will only precipitate in the 7 to 9 pH range. Ferrous iron is easily converted to the ferric state if oxygenated fluids are present. Iron scale from corroded tubulars (drill pipe, tubing and casing)

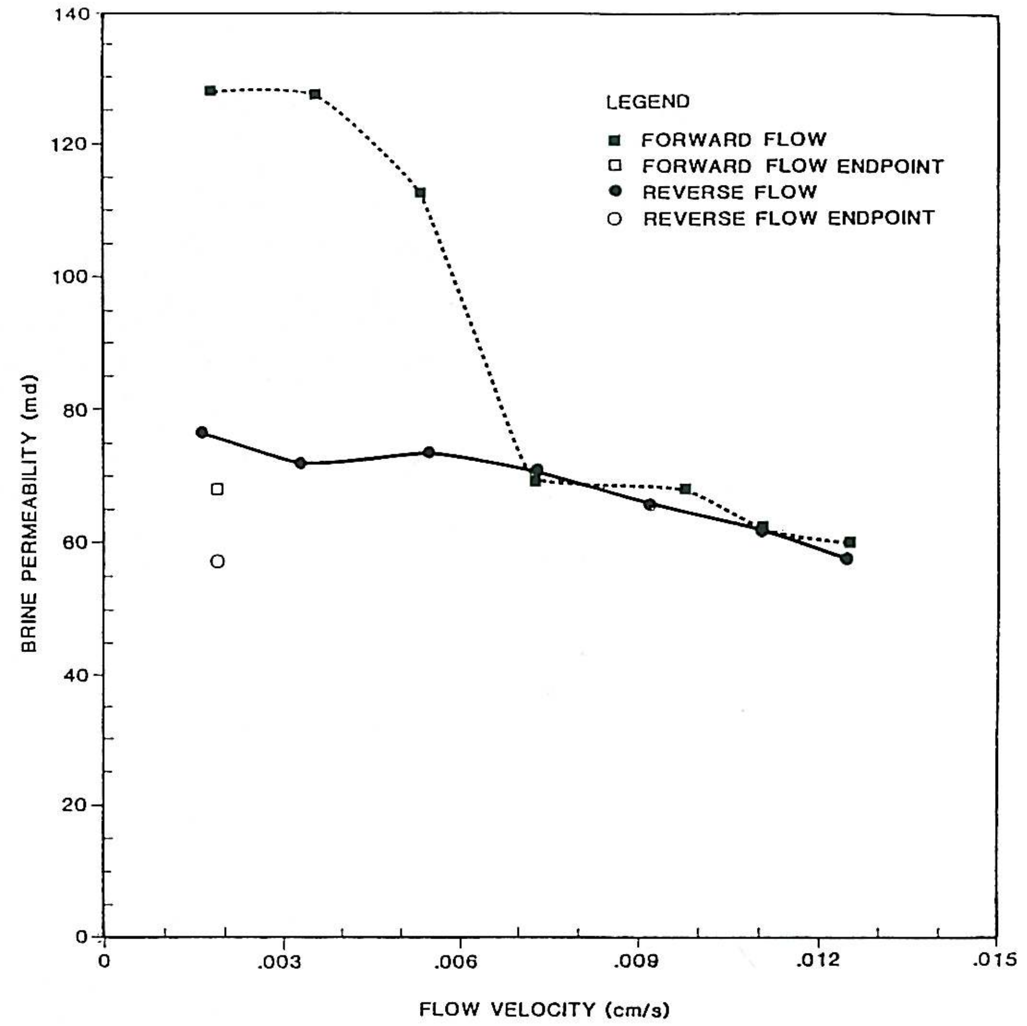

FIG. 2(a). Fines mobilization results showing significant damage (glauconite formation).

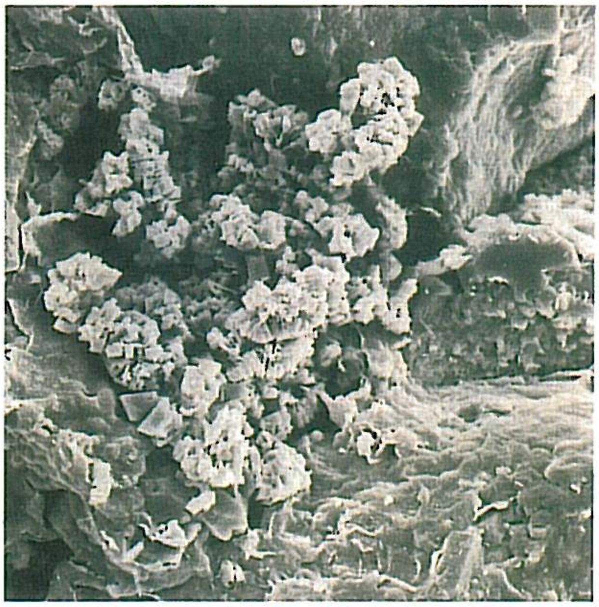

FIG. 2b. SEM view of the Messla Field sandstone showing potentially migratable authigenic kaolinite.

is also a major source of iron hydroxide precipitation.

Iron sequestering (chelating) agents can be effective in preventing iron hydroxide gel precipitation (Smith, *et al.*, 1965), forming a stable complex with dissolved iron and keeping it in solution. Oxygen scavengers prevent conversion of ferrous iron to the more dangerous ferric iron. It is important to determine the optimum concentration of sequestering agents, overuse may result in severe gel precipitation (Smith, *et al.*, 1965). Organic acids such as acetic, citric and lactic acids are commonly used as sequestrants in hydrochloric (HCl) acid treatments. If the treatment acid is recovered rapidly, the pH may not rise above 2 and dissolved iron can be maintained in solution without a sequestrant. Once iron precipitation has damaged the near wellbore area, a small-scale fracture treatment may bypass the damage.

(ii) Hydrofluoric (HF) acid is normally used in conjunction with hydrochloric (HCl) acid to remove drilling mud damage in sandstones (Hendrickson, 1965). HF acid will dissolve silicates (including quartz, feldspar and clay) and carbonates though the reaction rate is low compared to the reaction of HCl acid with limestone. The most common combination of the two acids (often called "Mud Acid") is 12% HCl–3% HF. Hydrochloric acid (acts as a converter to produce HF acid from ammonium salt), dissolves HCl-soluble material to prevent the HF acid from spending too rapidly and prevents the precipitation of calcium fluoride (CaF_2).

In poorly designed "Mud Acid" treatments, calcium fluoride (CaF_2), sodium fluoride (NaF) and/or sodium silicate (Na_3SiO_6) precipitates may significantly reduce near wellbore permeability. Unless carbonate material is removed prior to injection of HF/HCl acid into a zone, significant fluoride precipitation will result. Therefore, mud acid is not used in carbonate reservoirs and it should always be preceded by an HCl acid preflush in a sandstone to remove carbonate material. Reactions between sodium-rich formation fluids, feldspars, clays and HF acid can result in sodium silicate and fluosilicate precipitates; therefore, the use of HF/HCl acid treatments should be considered carefully.

(iii) Release and subsequent movement of "fines" to pore throats may create severe permeability drops in carbonates and carbonate-cemented sandstones. Carbonate material may be only partially dissolved, resulting in mobile carbonate remanat "fines" which could block pore throats.

(iv) Excessive dissolution of carbonate zones can result in significant permeability reduction from fabric collapse.

(v) Hydrochloric acid may react with oil to form solid or semi-solid particles called sludge; this material can severely restrict or completely plug the near wellbore area. Sludge problems are most common in Alberta and California.

Viscous emulsions (a mixture of two immiscible liquids) may form when treatment acid (water-based) contacts reservoir oil, severely inhibiting production.

Both sludges and emulsions may be removed by using appropriate surfactants (surface active agents), which reduce interfacial and surface tension and resulting a more miscible mixture of oil and water (acid).

In certain areas, the base of the Khalifa Formation is a ferroan dolomite cemented arkosic sandstone (Fig. 3). Iron within the dolomite cement may react with spending treatment acid to precipitate permeability – reducing iron hydroxide gels.

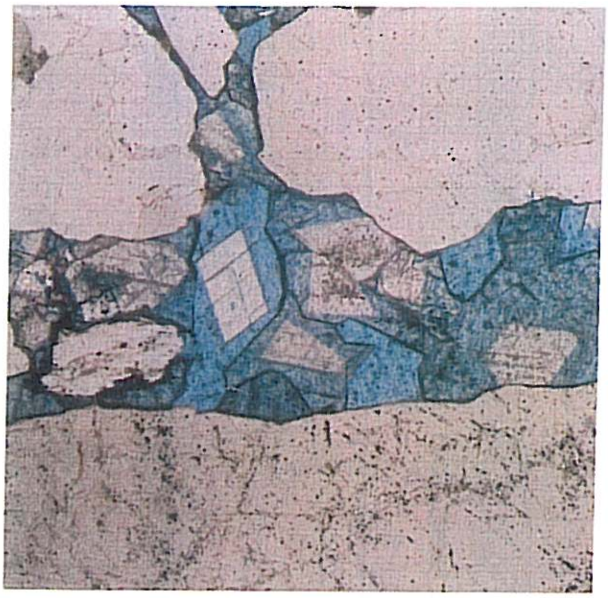

FIG. 3. Thin section view of a ferroan dolomite (stained blue) cemented arkosic sandstone with the Khalifa Formation. Iron within the dolomite could react with spending treatment acid to precipitate damaging iron hydroxide gels.

WATER SENSITIVITY

Within a reservoir, clay minerals are in equilibrium with interstitial brine and are generally in a flocculated, non-expanded state. Introduction of fresher water into a water sensitive reservoir may result in significant permeability reduction as a consequence of one or both of the following phenomena:

(i) clay swelling
(ii) clay deflocculation

(i) If fluid with a lower cation concentration (fresher water) is introduced into a zone with swelling (smectitic) clays, significant swelling and dispersion of these clays may result in severe permeability reduction. In addition, large volumes of fluid trapped within the expanded clay lattice may indicate a high water saturation (Sw) on logs, even though the zone could produce water-free hydrocarbon.

Expandable clays include all those in the smectite group, including mixed-layer clays such as smectite-illite (the most common) and smectite-chlorite (corrensite). Smectite, the only clay that swells, has weak internal bonding within its crystal lattice which allows cations such as Na^+, Ca^{2+} and K^+ to occupy interlayer positions. These cations are readily displaced by water molecules, which occupy a greater volume than the displaced cations, thus resulting in significant expansion of the lattice (from 10A to 20A). The degree of swelling is dependent on the original cations and the composition of the pore water.

The most effective and inexpensive clay stabilizer is KCl (potassium chlorite), generally in brine concentrations of approximately 3%. Potassium can replace sodium and calcium cations within the crystal lattice, resulting in stronger interlayer bonding. Cationic polymers (hydroxyaluminum, zirconium oxychloride), have also been used as clay stabilizers, but are expensive.

(ii) Kaolinite and illite, the most common clays in sandstones, do not swell if contacted by relatively fresh water; however, severe permeability reduction may occur as a result of deflocculation and subsequent migration of these clays. Johnson and Norton (1941) have proposed a double-layer concept to explain flocculation and deflocculation. When clays are submerged in water containing an electrolyte, an inner layer of negatively charged hydroxyl ions (OH) and an outer layer of positively charged cations, forms on the surface of the clay. The clay is flocculated when the cation is close to the clay surface and deflocculated when the cation is relatively distant. Apparently Ca^{2+}, Mg^{2+} and H^+ cations promote flocculation whereas Na^+ creates deflocculation.

Core flow tests have shown that problems related to clay deflocculation are most severe when a rock is "shocked" by flowing significantly fresher water through the pore system (Mungan, 1965). If the salinity of the injected water is gradually reduced from the original formation salinity to fresh, permeability reduction is minimal (Khiler, *et al.*, 1983).

Commercially available clay stabilizers (polyacrylamides, asphaltenes and resins, polyvinyl alcohol, hydroxyaluminum, etc.) coat clay surfaces, isolating them from changes in pore fluid composition (Sydansk, 1983). However, these stabilizers may themselves result in permeability reduction by taking up pore volume.

PORE TYPES

With respect to hydrocarbon production there are basically two types of pores:

1. Effective Pores:
    - Intergranular/Intercrystalline
    - Secondary Dissolution (Granomoldic)/ Biomoldic
2. Non-Effective Pores:
    - Secondary Dissolution (Granomoldic)/ Biomoldic
    - Microporosity

Obviously it is very important to determine the proportion of these two pore types in a reservoir in order to accurately predict reserves, sweep efficiency, etc.

EFFECTIVE PORES – Intergranular pores are generally well connected to each other and the associated permeability in a "clean" (clay-free) porous sandstone is usually high. Intercrystalline pores represent the carbonate equivalent of intergranular pores. Secondary dissolution pores are created by the leaching of unstable framework grains (feldspar, chert, rock fragments). If these pores are connected by a network of intergranular pores they contribute to permeability and are effective. The same is true for effective biomoldic (vuggy) pores, created by dissolution of fossil fragments and connected by intercrystalline pores.

In pore systems dominated by effective porosity, there is a "normal", roughly linear relationship between porosity and permeability, i.e. one increases with the other.

NON-EFFECTIVE PORES – In cases where secondary dissolution or biomoldic pores are the dominant or only pore type, the permeability may be anomalously low because of the generally isolated character of these pores.

Microporosity, commonly associated with detrital and authigenic clays, is generally non-effective with respect to hydrocarbon production, as a consequence of the very high capillary pressure forces at the small pore throats. These micropores may contain significant volumes of bound (connate) reservoir brine or hydrocarbon. "Dirty" (argillaceous) sandstones may contain large proportions of connate water in micropores, leading to a "wet" response on the resistivity log, yet the zone may produce water-free oil or gas. In argillaceous sands, the amount by which core analysis (total) porosity exceeds thin section (effective-visible) porosity is generally considered to be representative of microporosity.

Where pore systems are dominated by isolated non-effective pores, the relationship between porosity and permeability can be complex and non-linear. At low porosity values, the relationship with permeability may be linear, suggesting that this portion of the pore system is interconnected and effective. As porosity increases there is very little increase in permeability, indicating that this portion of the pore system is non-effective (either micropores or isolated dissolution/biomoldic pores).

Pitman (1979) suggested that there are four basic pore types in sandstones: intergranular (effective), dissolution (effective to non-effective), micropores (non-effective) and fractures (effective). The first three pore types can be called matrix related porosity. Understanding the pore geometry is essential in predicting the productive capability (recovery efficiency) of a reservoir. Logs cannot distinguish between effective and non-effective pores, the distribution of which affects the recovery efficiency, reserves, sweep efficiency, etc.

Another excellent paper on pore systems was written by Wardlaw and Casan (1978), in which they attempted to estimate recovery efficiency by quantifying visual characteristics of pore systems. They considered the following parameters to be of prime importance with respect to oil recovery: pore to throat size ratio; throat to pore coordination number; and type and degree of nonrandom heterogeneity.

The impetus for their work was the lack of relative-permeability data (which is required to estimate oil-recovery efficiency), because of the high cost of these tests. Using their visual method a large number of samples can be examined cheaply, providing a more representative sample base for relative-permeability measurements.

The Zelten Porosity Zone of the South Nasser Reservoir in the Sirt Basin, Libya is predominantly a foraminifera and echinoderm packstone with a pore system dominated by intercrystalline microporosity (Fig. 4a). Larger, intraparticle, vuggy and moldic pores, constitute a relatively minor part of the pore system and are isolated from each other by the micropores in the micritic matrix (Fig. 4b). As a result, permeabilities are anomalously low (generally less than 40 mD) compared to the high porosity values (20% to 28%) and recovery efficiencies are also expected to be low.

The Khalifa limestone also has a pore system dominated by micropores, with isolated molds and vugs (Fig. 4c).

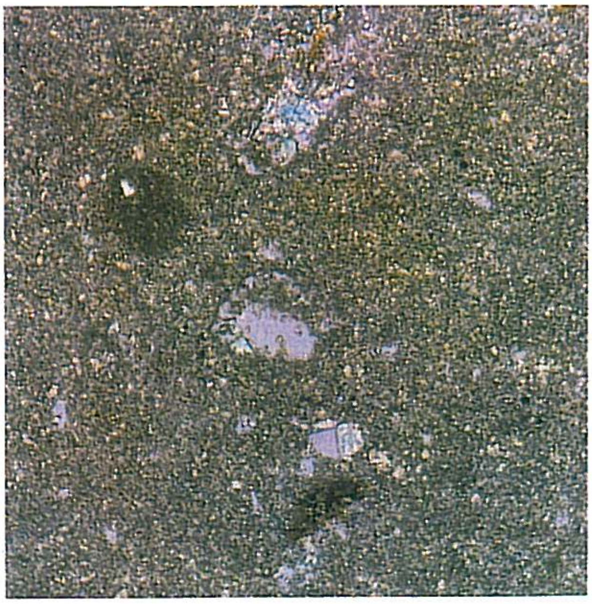

FIG. 4a. Thin section photomicrograph of the Zelten Porosity Zone in the South Nasser Reservoir, Libya, showing a pore system dominated by intercrystalline microporosity.

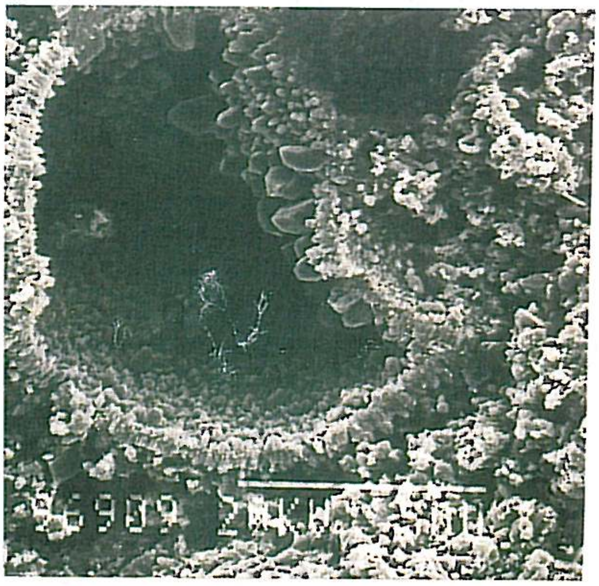

FIG. 4b. SEM view of intraparticle vugs within a foram test. Note the microporous intercrystalline porosity surrounding the vugs.

FIG. 4c. The Khalifa limestone also has a pore system dominated by micropores with isolated molds and vugs.

DRILL CUTTINGS

To an ever increasing extent, drill cuttings form the basis for reservoir quality and fluid sensitivity studies. This is an encouraging sign, suggesting that more and more geologists realize the value of these tiny pieces of reservoir.

Unlike cores, which only represent a small section of the wellbore, drill cuttings are usually caught over most productive zones. In addition, while only about one in three wells are cored, drill cuttings are caught on most wells. It is easy to see that humble drill cuttings hold a lot of potential.

A wealth of extremely useful information can be obtained from thin sections and scanning electron microscopy (SEM) examination of drill cuttings. This includes: framework mineralogy; diagenetic mineral suite; clay component; pore types and much more. In many cases, permeability and core analysis porosity can be empirically derived from cuttings by comparing them to data from adjacent cores.

Preparing thin sections from drill cuttings is relatively quick and easy. The initial step involves the selection or "highgrading" of cuttings assumed to be representative of the reservoir section. This is accomplished by using a binocular microscope, a good pair of tweezers and a pair of "sharp" eyes. Approximately twelve to fifteen drillchips are placed on a glass slide, impregnated with blue epoxy and ground to a thickness of 30 microns. SEM preparation requires selection of representative drill chips, mounting on an aluminum stub and gold coating prior to examination.

In general, cuttings represent the more competent, better cemented part of the reservoir; the proportion of diagenetic cements is anomalously high and porosity values are conservative with respect to the situation in the reservoir. As a consequence, the accuracy of porosity and permeability determinations based on drill cuttings is highly dependent on the experience of the interpreter.

Empirical derivation of permeability and core analysis porosity from drill cuttings can be accomplished by comparing data from drill cutting thin sections (Figs. 5a and 5b) with thin sections from an adjacent and equivalent cored zone.

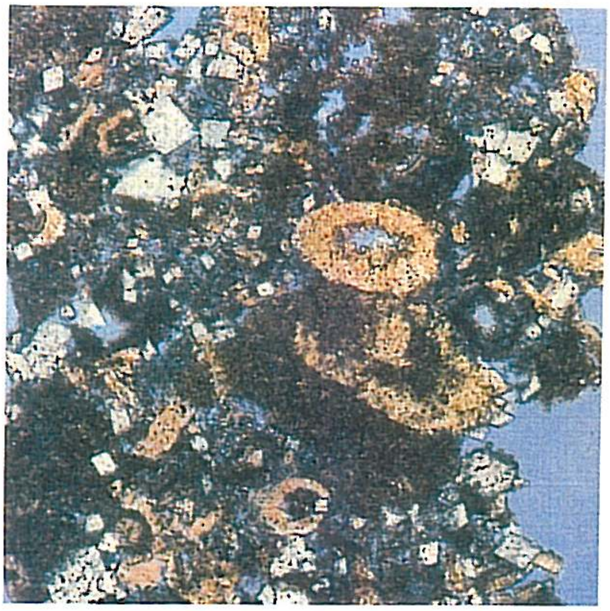

FIG. 5a. Thin section photomicrograph of a peloidal echinoderm grainstone drill cutting in the initial stage of dolomitization.

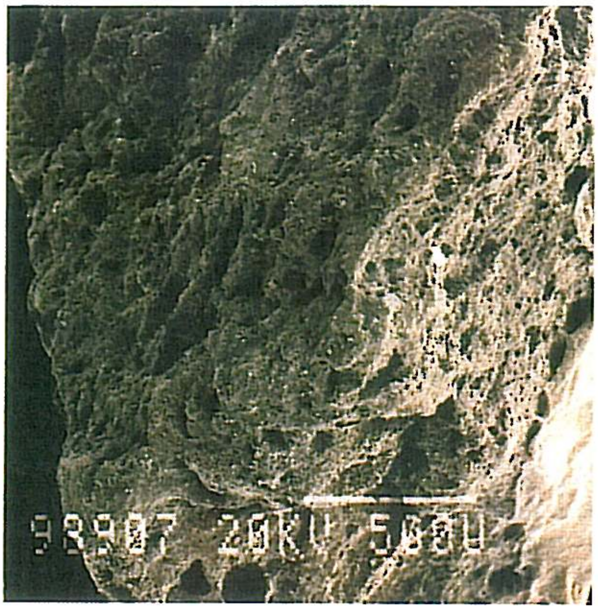

FIG. 5b. SEM view of a dolomite drill chip with isolated micro-vuggy porosity.

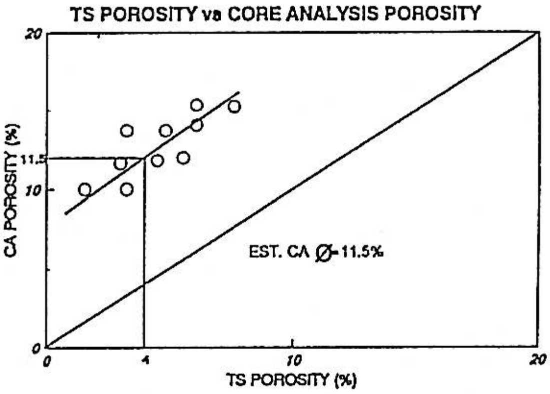

FIG. 5c. Thin section data from an adjacent cored section is plotted to provide a trend line relating core analysis porosity to thin section porosity. Core analysis porosity can then be derived by cross-plotting thin section porosity from the drill cuttings.

Core analyses porsity and permeability will be available for the thin sections prepared from core. These parameters can be plotted against thin section porosity which is obtainable from the drill cutting thin sections.

Initially, core analysis porosity is plotted against thin section porosity for the cored section to derive a trend line relating the two parameters (Fig. 5c). Thin section porosity for the drill cutting samples is then plotted to the trend line to obtain an equivalent core analysis porosity.

The empirical core analysis porosity for the drill cuttings (checked against log porosity for accuracy) is then plotted to the trend line relating per-

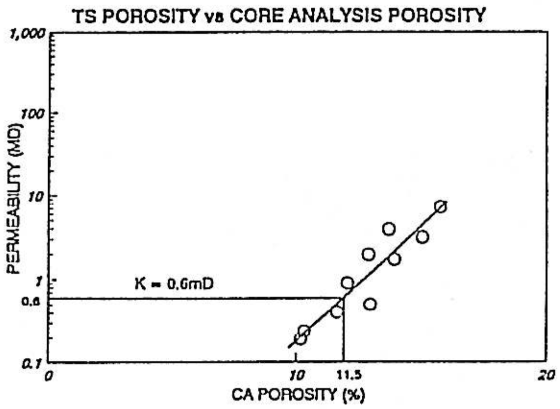

FIG. 5d. The empirical core analysis porosity derived from the drill cuttings (check against log porosity for accuracy) is then cross-plotted to provide permeability for the drill cuttings.

meability and core analysis porosity (Fig. 5d) to provide an empirical permeability value for the drill cuttings.

SUMMARY

Reservoir Quality analysis, incorporating thin section petrography, scanning electron microscopy and X-ray diffraction techniques, is very useful for predicting potential fluid sensitivity problems within reservoirs. These potential problems include fines migration (Messla Field Sandstone), acid sensitivity (Khalifa Formation) and swelling clays. Also, distinguishing between effective and non-effective porosity (Khalifa and Zelten Formations) can be accomplished using thin section petrography. Determining the propotion of effective porosity within a reservoir is obviously important with respect to reserves, sweep efficiency, recovery efficiecy, etc.

Thin section and SEM examination of drill cuttings is very useful for determining reservoir quality and fluid sensitivity of prospective reservoirs. Framework mineralogy, diagenetic mineral suite, pore types, permeability and core analysis porosity can often be derived from drill cuttings.

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