Physical and Chemical Properties of Crude Oils and Their Geologic Significances

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Abstract: ***Crude oils are naturally occurring liquid phase of petroleum, composed principally of hydrocarbon compounds and are extracted from the earth in the liquid state. The hydrocarbon compounds in crude oils include paraffins ranging from pentane to pentadecane ($C_5 – C_{15}$), alkylparaffins, naphthenes, alkylbenzenes and nuclear aromatics. Other associated matters are natural gases, hydrocarbon waxes, and salt water. Crude oil can be described as paraffin base, naphthene base or mixed base, depending on the most abundant group of hydrocarbons contained. Crude oils also contain a variety of other chemical constituents comprising of sulphur, oxygen, carbondixode, nitrogen and trace metals. Crude oils are characterized by some physical and chemical properties, which to a measurable extent, play important role in the understanding of the oils geologic nature and environment of origin, such a physical property as optical activity is dependent on hydrocarbon derivatives from organic cholesterine substances, and are destroyed at high temperatures of about 200^0C. They serve as important tools for environmental analysis, reconstruction of temperature history of the oil, and correlation of crude oils of similar geologic ages. Cloud and pour points of crudes reveal the influence of low temperatures on crude oils and simultaneously, provide information about the paraffin wax content of the crude. Most of the physical properties of crude oils such as A.P.I. gravity, viscosity and coefficient of expansion, depend on reservoir pressures and temperatures, chemical composition of the oil, and sometimes, on the amount of dissolved natural gases. The chemical properties of crude oils vary in relation to changes in geotemperatures and pressure, coupled with some other elements of katagenesis. The paraffin wax and porphyrins are complex forms of hydrocarbons which have genetic relationship with living organic matters. Occurrence of isoprenoid hydrocarbons such as pristanes and phytanes, in crude oils help in the reconstruction of the genetic environments of deposition of the source rocks. Trace metal substances concentrated in oils are thought to be derivatives from sea water as secretions by marine organisms. The economic value of any crude is influenced by such properties as A.P.I. gravity, paraffin wax content and sulphur content. The aforementioned properties of crude oils apply to the Nigerian crudes. Their A.P.I. gravities change abruptly after a certain depth, where there is a marked change in temperature. Nigerian crude oils are generally light, low sulphur-bearing, and are in great demand by advanced countries.***

1. Introduction

Crude oil is a naturally occurring liquid phase of petroleum, composed principally of hydrocarbons, extracted from the earth in liquid state, or is capable of being so removed. It is mostly found in association with natural gases. Other associated materials include solid hydrocarbon substances such as waxes and asphalt, and salt water.

2. Chemical Composition of Crude Oils

Crude oils are made up of liquid paraffin hydrocarbon compounds ranging from pentane to pentadecane ($C_5 – C_{15}$). These hydrocarbon compounds consist of different groups such as the normal paraffins, iso-paraffins (branched chain paraffins), alkyl paraffins, naphthenes (or cycloparaffins), alkylbenzene and nuclear aromatics. The normal paraffins are the saturated, low molecular weight hydrocarbons. The associated gaseous phases are within this group. The naphthenes (or cycloparaffins) are highly bonded, high molecular weight hydrocarbons. All crude oils contain some appreciable amount of the naphthene compounds, (10% by composition).

Crude oils also contain a great variety of heteroatomic chemical constituents, comprising of sulphur, oxygen, carbondioxide, nitrogen and trace metals. Nitrogen varies from 0.01 to 2% as dissolved gas in the crude oil (Levinson, 1974). Oxygen occurs in different forms in oxygen-bearing resinous substances.

Crude oils accumulate in geologic structures called 'traps'. A trap can be stratigraphic, paleogeomorphic or a combination of these. Palecgeomorphic traps includes structural folds and stratigraphic traps are those caused by lateral changes in reservoir rock properties within a stratum.

3. Physical Properties of Crude Oils

The physical properties of crude oils are the quantitatively measurable characteristics of crude oils. They vary according to the composition of the oil, the relative abundance of the groups of hydrocarbons, and essentially depend on reservoir temperatures and pressures.

Specific (or A.P.I) Gravity

This is the weight of a given volume of crude oil. It is measured in two gravity scales, as stated below:

i. A.P.I. gravity (in degrees) = $\frac{141.5}{\text{SP.gravity at } 60^0\text{F}} - 131.5$

ii. Baume gravity (in degrees) = $\frac{140}{\text{SP.gravity at } 60^0\text{F}} - 130$

The A.P.I. (American Petroleum Institute) gravity scale is more commonly and widely used than the European Baume gravity scale. But they essentially measure the density of a crude oil. The A.P.I. gravity of a crude is influenced by the composition of the oil. Crude oils characterized by high amount of dissolved gases, are less dense thus, light in weight and therefore, possess high A.P.I. gravities, while denser crude oils of low amount of dissolved gases are characterized by low A.P.I. gravity values.

The group of hydrocarbons predominating in a crude oil also influences the A.P.I. gravity. For example, paraffin base crude oils (45-60% paraffin hydrocarbons and less amount of naphthenes and aromatics) are light, thus, high A.P.I. gravities. But naphthemic base crudes (consisting predominantly of naphthene hydrocarbons 60-75%, with lesser amount of paraffins and aromatics) are heavy and have low A.P.I gravities?

The A.P.l. gravities of crude oils usually increase with depth. This is because a combination of source and reservoir maturation processes, Associated with slow but continuously increasing geotemperatures, cause the generation of lighter (or High A.P.I gravity) oils at greater depths of burial.

Viscosity

This is the measure of resistance to flow in crude oils due to internal friction. It is expressed in 'poise' or 'centipoise'. crude oil is said to have a viscosity of 1 poise when a tangential force of 1 dyne causes a plane surface of 1 square centimetre area; spaced 1 cm from a stationary plane surface to move with a constant velocity of 1 cm per second, the space being filled with the viscous c.

The viscosity of a crude oil is influenced by the amount of dissolved gases at the prevailing temperature. Crudes characterized by high amount of dissolved gases have high A.P.I gravities and low viscosity or moderately high fluidity; illustrated in figure 2. At high temperatures molecular agitation (or velocity) of the crude increases, making for a volumetric expansion and reduction in internal molecular friction, thus, reducing the oil. The greater the quantity of a high-molecular weight hydrocarbon group in a crude, the denser and more viscous.

Refractive Index

The refractive index n, of a crude oil is measured from

$$n = \frac{\mathrm{Sin}i}{\mathrm{Sin}r}$$

where; i = incidence angle
r = angle of refraction

It depends on the density of the oil. Heavy crudes (of low A.P.I) have high refractive indices. This is because a dense crude would create a dense medium for a passing ray of light, which is refracted towards the normal at a low angle (r). On the other hand, light oils have low refractive indices.

Optical Activity

Optical activity is the power of crude oils to rotate the plane of polarization of a polarized light. It is commonly expressed in degrees per millimetre. If any crude oil causes the plane of polarization to rotate to the right, it is called a 'dextroratory', but if is to the left it is known as a 'levorotary'. This property is destroyed at high temperatures (250 - 300°C).

Optical activity is also exhibited by some organisms that contain cholesterine substances (such as cholesterol $C_{26}H_{45}OH$). According to Amosov (1951), the amount of optical rotation shown by a crude oil depends mainly on its sterane-pentacyclic and triterpane content. And these are hydrocarbon compounds derived from the microbial decarboxylation of organic cholesterine substances.

Cloud and Pour points

The pour point is the temperature at which a crude oil will no longer flow, when a tube containing it is first heated in a bath, in order to dissolve all its wax content and then gradually cooled. At this temperature, the crude oil is in semi-solid to solid form, and thus loses its fluidity. Slightly above this temperature of no-flow (the pour point), there might had been an appearance of cloudy substances in the crude; which is due to the settling out of the solid paraffin waxes contained in the crude oil. That temperature is called the cloud point.

This property determines the influence of low temperatures on crude oils. Simultaneously, it provides information about the amount of solid paraffin waxes contained in the oil. This property is common in paraffin base crudes but wax-free naphthenic oils do not show cloud point. If the pour point of a crude is above the surface temperature, it will precipitate its paraffin waxes on approaching the surface of the ground will only flow on heating. The range of pour points of crude oil varies greatly from -70^{0}F to +90^{0}F or higher.

Volume

The volume of a crude oil in its reservoir rock differs from the volume it occupies in the surface. This is due to formation gas-oil ratio and reservoir pressures. The formation gas-oil ratio expresses the volume of gas contained in one barrel of a crude oil as it comes from the reservoir rock. Under high reservoir pressure, the volume of oil in the reservoir increases because of the influence of dissolved gases. But on release of the reservoir pressures, the dissolved gases escape, leading to the shrinkage of the volume of the crude oil at the surface.

Flourescence

It may be yellow, green or blue. For example, when a paraffin base crude oil (gasoline-rich) is exposed to ultraviolet fluorescence light, it emits yellow colour, while naphthenic oils emit brownish colour This property is important in testing for cutting, core and drilling mud samples and in well-logging interpretation, for location of different oil horizons.

Colour

This is the light transmitted through crude oils. It is yellowish to red for light oils and dark or even opaque for heavy (or low A.P.I gravity) oils.

Some other Physical Properties

Odour

This varies greatly in crude oils. High content of light hydrocarbons (paraffins and naphthenes) in a crude gives rise to a gasoline-like odour. A pleasant odour is produced if the crude has abundant aromatic hydrocarbons. But with high amount of unsaturated hydrocarbon compounds, sulphur and nitrogen compounds in the oil, it produces a repugnant odour.

Coefficient of Expansion

This is the measure of volumetric increase of a crude under thermal influence. It increases with increase in A.P.I gravity. Oils containing high amount of (dissolved) gases and possibly of high A.P.I gravities possess high values of coefficient of expansion. Heavy crude oils (low A.P.I gravity) have lower coefficients of expansion.

Aqueous Solubility

The aqueous solubility of crude oil and its fractions increases linearly with temperature. The rate of solubility becomes significant at temperatures of about 100°C. At temperatures above 180°C, crudes occur as molecular solutions in mixed phase with water. According to Cartmill and Dickey (1970), at such high temperatures, the nature of the phase enhances primary migration of oil by molecular solution mechanism. And salinity of about 150,000ppm of sodium chloride results in the seperation of liquid hydrocarbons from the aqueous phase.

Surface tension Effect

Crude oils possess some intermolecular forces of cohesion, expressed as force per unit peripheral outline. Because of this force, oil in dispersed state cannot move through water-wet sand, much less, fine-grained shales. The small forces created by natural hydrodynamic gradients do not overcome those created by surface tension. Consequent the oil is dispersed in the form of globules.

Flash Point

This is the temperature at which the volatiles rising off the surface of heated oil will ignite with a flash, on passing a flame over the surface. This provides some clew about the gaseous content of the crude oil.

4. Chemical Properties

The chemical properties of crude oil deal with the chemical nature and the changes in composition in relation to temperature and pressure variations occurring at all times within the oil pool. Some of the chemical properties are related to the origin, migration, and accumulation of the crude oil.

Chemical Nature

Crude oils are composed of liquid hydrocarbon compounds of: paraffin series ranging from pentane to pentadecane (C_{5}-C_{15}), varying amounts of naphthenes, alkyl benzenes, amomatics, trace amount of semi-solid to solid phase hydrocarbons such as asphaltic matters and waxes. Other secondary constituents are sulphur, nitrogen, oxygen, carbondioxidc, trace metals which include silicon, iron, aluminum, calcium, magnesium, copper, lead, tin, zinc, nickel, molybdenum and vanadium. Various hydrocarbon compounds in crudes have been isolated and analysed at different temperatures ranging from 40 – 180^{0}C. These hydrocarbons consist essentially of hydrogen and carbon. Some of the compounds are saturated with hydrogen while others are not.

A crude oil is categorized on the basis of the most abundant group of hydrocarbons it contains. A crude oil can be described as paraffin base, naphthene base or mixed base (i.e naphthenic-paraffin base) depending on the percentage composition of its hydrocarbon fractions, as demonstrated in Table 1.

The paraffin base crude oils have low density (high A.P.I gravities), and in chemical refineries yield high amount of gasoline and kerosene. The naphthene base crudes produce high amount of lubricating oils, less gasoline and kerosene as the refinery products.

Hydrogenation of crude oils

During the early stages of crude oil formation, there is a remarkable thermal cracking of the organic materials into decomposed complexes, and the coupling activity of anaerobic bacteria processes, and the catalytic influence of such available trace metals as vanadium and nickel, lead, to the transformation of the complex organic matter into alkene rich paraffinic oil. And according to Zobel (1947), reservoir catalytic chemical reactions lead to the dissociation of avail sulphides into free sulphur and hydrogen. The elemental hydrogen would convert the alkene rich paraffinic crude oil into an accumulation of gaseous paraffinic oils (of high A.P.I gravity), in relatively close association with the kerogen (or organic source rock).

Paraffin wax content

Paraffin waxes in crude oils are semi-solid to solid forms of hydrocarbons, consisting mainly of normal paraffins. These n-paraffins range from about C_5 – C_{30}. Admixtures of branched-chain paraffins are also contained. Hedberg (1968), described waxes as complex petroleum substances whose complexity is caused by molecular mixture of branched chain and n-paraffin hydrocarbons, with molecular weights, high enough to be solids at ordinary temperatures.

Paraffin waxes in crude oils have melting points above 30-35^{o}C. The amount of wax in crude oils varies very greatly. According to Levinson (1974), paraffin base and mixed base crude oils have high amount of paraffin wax up to about 1-6%. Hedberg (1968) stated that paraffinic-naphthenic (or mixed) base crude oils usually possess over 10% of paraffin wax, Naphthenic oils contain trace amounts of waxes (usually <1%)

Waxy oils may also contain soft waxes and nonwaxes composed of complex naphthene chains, naphthenic rings and polycyclic aromatic. They are separated by solvent crystallization into viscous oils, soft wax-like materials, and hard, dry microcrystalline solids.

High content of paraffin waxes in oils may lead to the clogging of pores of the reservoir rocks. Such oils congeal at atmospheric temperatures and exhibit high pour points.

Paraffin waxes are believed to be derived from land plant materials and other terrigenous organic matter of non marine environments.

Odd carbon Chain Lengths

Chemical analysis shows that some crude oils exhibit a detectable predominance of n-paraffins of odd number carbon chains over those of even Members. The odd carbon chains range from C_{17} to C_{33}. The ratio of the sum of the mole percentages of odd carbon n-paraffins to the sum of even Carbon n-paraffins in a specific molecular weight range, serves as an index of odd carbon preference. Welte (1965) believed that crude oils from different environments possess correspondingly different odd carbon preference indices.

Carbon Isotope Ratio

Most crude oils have been proved to contain varying amounts of carbon 13 and carbon 12 isotopes. And the concentration of these isotopes varion crudes of different source environments. According to Silvermann and Epstein (1959), the ratio of C^{13}/C^{12} isotopes in crude oils is found to be nearly analogous to those of living organic matter. This property thus, establishes a relationship between crude oils and organic sediment. Welte (1965) found that the quantity of isotope carbon-13 in crude oil is significantly different for oils from reservoirs of varying geologic ages.

Sulphur and Its Isotope Ratio

In crude oils, sulphur occurs as free sulphur, hydrogen sulphide and in organic sulphur compounds such as thiols and disulphides. Sulphur occurs in trace quantities of about 0.1 to 5.5% by weight in oils.

Lijubach (1975) traced sulphur occurrence in oil to the genesis of the oil. He believes that bacterial reduction processes convert sulphates into hydrogen sulphides and free sulphur. And if the environment is rich in trace metals, available meteoric water would enhance the oxidation of the sulphides into metallic sulphides and hydrogen. These metal sulphides do not influence the composition of the crude. But if the environment is deficient of trace metals there would be direct bacterial oxidation of hydrogen sulphide into elemental sulphur thus producing a sulphur rich oil. This is illustrated' in Fig. 4. High amount of sulphur is found in association with high molecular weight hydrocarbons, (asphaltenes inclusive) Fig. 5. High content of sulphur and its compounds corrodes the refinery installations when such crudes are refined.

At temperatures higher than 150^0 C, sulphur reacts with some hydrocarbon compounds in the crude to produce thiols and mercaptans. Therefore the presence of elemental sulphur in crude oils suggests a relatively lev: temperature history (Lijmbach, 1975).

Porphyrins in Crude Oil

Porphyrins are complex hydrocarbon compounds that originate from living organic matters such as chlorophyll and hermins. The basic structure of porphyrins consists of four interconnected rings, each ring containing four carbon atoms and four nitrogen atoms.

According to Hodgson et al (1967), porphyrins have high affinity for trace metals of vanadium, nickel, and iron. This property enhances the hybridization of unstable porphyrin substances with nickel or vanadium to produce metal-porphyrin complexes. The latter is produced by the simplification of the ring structures of the chlorophyll matter coupled with the replacement of the magnesium metal atom in the centre, by such trace metals as V, Ni or Fe, thus producing a metallic porphyrin complex. The latter exists more stably in the crude oil, as it offers more resistance to degradation and alteration.

Chemical investigations have shown that paphyrins are one of the important constituents of crude oils. They are commonly associated with isoprenoid hydrocarbon forms; pristane and phytane. According to Hunt (1968), these hydrocarbons are derivatives from marine phytoplankton. The long-side chain characteristics of the chlorophyll molecule readily break off to form phytol. And the phytol can either be oxidized to form pristance or be reduced to form phytane, depending on the redox potential of the environment. Other hydrocarbon groups associated to porphyrins include carotene and terpenoid structures.

Porphyrin substances are of moderately low temperature origin, usually destroyed at temperatures of about 200°C. Thus, their presence in crude oils is an indication that the crude was formed at temperatures below 200^0C

Trace Metals in Crude Oils:

Crude oils contain varying amounts of trace elements some of which include, iron, aluminium calcium, magnesium, copper, lead, tin, astemum, antimony, zinc, silver, nickel, chromium, molybdoniura and vanadium. But the most important of these trace elements are vanadium, nickel and iron. The concentration of any of these trace metals is so small that the value is expressed in parts per million. The concentration of trace metals in any crude oil is found to be inversely proportional to the A.P.l gravity of the oil.

Some Other Chemical Properties

Effect of Carbondioxide and Saline Water

High amount of anaerobic microbacteria in some reservoir rocks generate carbondioxide, which in association with hydrocarbon gases, constitute dissolved gases that mobilize the liquid hydrocarbon. The carbondioxide facilitates a decrease in viscosity of the oil and generates internal gas pressure to drive the crude oil from dead-end pockets and through interstitial spaces.

When these gases are dissolved in saline water, sufficient reservoir drive to flow light paraffin base oils is provided. The saline nature of the water reduces its surface tension, thus, creating molecular contact between water and the crudes, subsequently, leading to the effective mobilization of the crude oil.

5. Geologic and Economic Significance of Some Properties of Crude Oil

Criteria for Environmental Interpretation

Some properties of crude oils have contributed immensely towards the analysis of the environments of occurrence of the crudes and the understanding of their mode of origin.

High wax content in crude oils is a property commonly associated to the genetic environment or the kind of organic matters from which the oil was derived. Paraffin waxes are however conceived to be derived from terrigenous materials (land plants) in the source rock. This is characteristic of paralic to paralic marine environments. Its lithologic sequences are characterized by sandstone and shale intercalations, often waxy oils are associated with interfingering of continental and marine sediments, and may contain some lenses of coal and oil shales. Hedberg (1968) thought that waxy oils are of fresh to brackish water origin, occurring in continental, paralic or nearshore environments, examples of waxy crude oils of such environments are those of Nigeria and Eastern Venezuela.

The environment of deposition of source rocks of crude oils can be discerned from the hydrocarbon-sulphur-nitrogen compositional association. This is shown on Table V.

Optical activity is a physical property of oils which establishes some relationship between crude oils and marine or near marine environments. This is because of the occurrence of cholesterine substances (source of optical activity) in both exude oils and some marine organisms.

Trace metal complexes occurring in crude oils are considered as important indicators for environmental interpretation. Such trace metals as vanadium, nickel, iron, silicon are believed to have formed from marine organic secretions or from planktonic organisms. And the presence of these elements in a crude suggests that the oil must have formed in a marine environment. Hodgson and Baker (1957) held the view that the presence of iron-porphyrins in crude oils is an indication of source of marine origin. They argued that the characteristic high pH values of about 8.5 for marine environments favour high concentration of $iron_0$

Carbon isotope ratios (C^{13} /C^{12}) in oils are suggestive of the source rock environments. The carbon isotope ratios of crude oils vary with their environments of formation. Silvermann (1960) found that the average C^{13} /C^{12} ratio for oils of marine environment is greater than 1% whereas the value decreases in oils of nonmarine environment.

Hydrocarbon compounds such as porphyrins and isoprenoid compounds which occur in crude oils contribute immensely to the reconstruction of temperature and paleoenvironraental history of the oils. The ratio of some isoprenoid compounds (pristane-to-phytane), contained in any crude oil is a function of the redox potential of the oil's source rock environment of deposition. According to Lijmbach (1975), certain relationship has been observed between isoprenoid composition of crude oils and their source rock environment of deposition.

1) Peat swamp conditions were characterized by low pH, of 5, low oxygen content and presence of toxic compounds, thus enhancing anaerobic bacterial activity and decarboxylation of phytanic acid. This leads to generation of pristine rich oils characterized by the Pristane-to-heptadecane ratio greater than unity. But the redox potential of the environment do not favour generation of phytane-rich crude oils.
2) Source rocks deposited at open water environment generated oils of low pristane/C_{17} (heptadecane) ratios.
3) Source rocks of alternating swampy and open water conditions produce oils of intermediate-Pristane/ n-heptadecane ratio.

Criteria for Geologic Interpretations

Optical activity in crudes serves as an important tool for correlation of oils of similar geologic ages. This property depends on the amount of cholesterine substances in the oil. There prevails a transformation of the triterpane and sterane hydrocarbons into polycyclic naphthenes thus, causing a gradual depletion of the concentration of the cholestorine substances with geologic age. Optical rotations of younger crude oils are usually greater than those of older rocks. Amosov (1951) measured the optical rotation of several crudes in USSR, and arrived at a conclusion that crude oils of Tertiary age have optical rotations above 1^0, while those of Mesozoic and Paleozoic oils were below 1^0.

Table VII shows the change in optical rotation of crude oils with Age. Trace metals are used in geologic interpretation on the basis of the vanadium-to-nickel ratio. Nickel substances in crude oils are more stable than those of vanadium. These metals enter the oil substance very early in its history and leave the substance at unequal rates as the oil matures in its reservoir rock. This gives rise to a net change of the vanadium-to-nickel ratio toward a lower value as the oil becomes older. Hodgson (1954) noted a uniformity in the trend of variations of vanadium nickel, sulphur, resins and increasing asphaltene content in the crude oils of Western Canada. He regarded this trend as a product of alteration. All these characteristics of trace metals in crude oils earn them a recognition as sensitive indicators of alteration and geologic age.

The sulphur isotopic ratio (S^{32} /S^{34}) of crude oils help in the correlation of oils of different source rocks and those of different stages of maturation. Though there occurs some loss of sulphur during maturation and weathering of the crude oils, sulphur isotope ratios show little or no change. Thus, the presence of high sulphur isotopic ratios and generally low sulphur content is indicative of alteration. Very viscous crude oils may suggest some degree of weathering in highly fractured basins.

Criteria for Economic Significance

Some physical and chemical properties of crude oils determine their economic value. Such properties are the A.P.l gravity, wax content, sulphur content and the type of dominant hydrocarbon group (or fractions) of the crude oil. Furthermore, the economic significance of a crude oil also depends on the immediate requirements of the consumer or country. For example light paraffinic (of high A.P.I gravities) oils yield high amount of gasoline and, kerosene as the refinary products. Such countries as India desiring greater supply of kerosene, for domestic source of heat have high demand for crudes that give maximum percentage of kerosene on refining. Crude Oils of moderate gravities (mixed and naphthenic base crudes) are of high demand by advanced countries. This is because of great need for lubricating (industrial) oils and gasolines in such countries for example; U.S.A. makes high demand for both naphthenic and light paraffin oils. Generally however, there is usually a great demand for oils of A.P.I gravities ranging from 20° to 45°. Very light oils (of high A.P.l gravities) and heavy oils (of low A.P.I gravities) can be blended to meet the requirements of the consumers.

The amount of paraffin wax contained in a crude oil influences its economic evaluation. Waxy crude oils are characterized by low calorific values, thus a low capacity to generate heat. This limitation therefore earns any waxy crude oil a relatively low price.

Occurrence of sulphur in crude oils is of negative economic significances. This is because; high content of sulphur in a crude creates corrosive effects on refining columns. And any installation of special sulphur-resistant steel columns is usually very expensive. The processes of removal of sulphur from crude oils are also expensive and time consuming. Moreover, refining of sulphur bearing crude oils create strong environmental pollution. All these amount to a decrease in demand for, or subsequent reduction in the price of sulphur bearing crude oils.

Broadly speaking however, the prices of typical crude oils of all the member countries of OPEC countries are determined by the Organization of Petroleum Exporting Countries (O.P.E.C).

6. Some Characteristics of Nigerian Crude Oils

A.P.I Gravity

The A.P.I gravities of crude oils of the Niger delta do not exhibit a very consistent trend. The A.P.I gravities of Nigerian crude oils vary from 30^0 to 40^0 A.P.I. They change abruptly after a certain depth called the critical depth. The trend of variation of A.P.l gravities of the oils corresponds with the direction of change from medium A.P.I gravity naphthenic oils to light paraffinic oils, as the depth of burial increases. The interface between the heavier and lighter oils is often described as the level of transformation. It is characterized by temperatures of about 60 - 80^0 C. According to Evamy *et al* (1978), the paraffinic oils below the level of transformation were produced by late migration from the source rock.

The accumulation of lighter paraffinic oils at greater depths of burial is as a result of the combination of source and reservoir maturation processes, associated with the high geotemperature conditions at such depths, (which ranges to about 100^0 - 115^0 C) , and other katagenetic processes.

In some of the oil fields of the Niger delta, extensively faulted reservoirs are thought to have created leakage channels through which inorganic agents such as oxygen and water drain into the reservoir.

These inorganic agents cause anomalous weathering of crude oils in the reservoir at high temperatures. Fig. 11 shows the faulted nature of the Niger Delta sediments.

Pour points

The pour points of crude oils from different oil fields of the Niger Delta show significant variation. This variation reflects a change in the most abundant group of hydrocarbons contained in the crudes. For example, paraffinic waxy oils of the Niger delta possess pour points ranging from 20 to 90^0F. But naphthenic nonwaxy oils of Niger Delta have pour points generally lower than - 25^0 F. (Frankl and Cordvy, 1967).

Paraffin wax Content

Most Nigerian oil fields depict a close intercalation of high wax and low wax oils. Some of the paraffin wax bearing crude oils produce as high as 5% wax content.

These waxes are believed to be derived from terrigenous (or land plants) materials of the source rock. Chukwuemeka and Okoye (1980) supported this view by their successful investigation of the presence of humic, vitrinite and liptinite particles in the Niger Delta source rock. These particles being indicators of terrestrial lithotypes. The widely supported view is that the source beds of the Niger Delta crudes are deeply buried paralic to marine Akata Shale, A schelaitic representation of the Niger Delta structures is shown in figure 12.

Influence of Geotemperatures

The nature of the crude oils in the Niger Delta is being controlled by geotemperatures, thermal maturation and depth of burial. Variation in these elements of katagenesis results in the production of paraffinic-rand paraffin-naphthenic crude oils. API gravities and pour points are low at cooler depths of the reservoir. At relatively higher subsurface temperatures, the crudes are light and characterized by pour points higher than 20^0F. The significance of geoteraperatures on the crude oils of the Niger Delta is not only reflected on the A.P.I gravity, but also in their viscosities and boiling point fractions.

The irregular variation in the properties of crude oils of multiple reservoirs of Niger Delta can also be attributed to random sand bodies that are interbedded with shales, and the influence of tectonic activity, high rates of subsidence and deposition of its source rocks.

Generally speaking, the Nigerian crude oils are light paraffinic, and paraffin-naphthene base crudes. They yield significant amounts of gasoline, kerosene, lubricating oils, and provide naphtha which can be the raw material for fertilizer industries. Some representative properties of Nigerian crudes are shown on Table VIII. Nigerian crudes are characterized by little or no occurrence of sulphur. This saves the expense of purchasing sulphur-resistant steel for refining installations, and also saves the time and expensive processes of removal of sulphur in crudes. These favourable factors make the Nigerian crude oils attractive in advanced countries.

7. Conclusion

Crude oils are naturally occurring liquid phase of petroleum, composed principally of hydrocarbon compounds and are extracted from the earth in the liquid state. The hydrocarbon compounds in crude oils include paraffins, ranging from pentane to pentadecane (C_5-C_{15}) alkylparaffins, naphthenes, alkylbenzenes and nuclear aromatics. Other associated constituents are natural gases, hydrocarbon waxes, and salt water.

There are three main categories of crude oils viz:

1) Paraffin base crudes: containing higher percentage-abundance of paraffin hydrocarbons, and yield more gasoline and kerosene as refinery products.

2) Naphthene base crudes: containing greater amount of naphthenes and aromatica, and yield more lubricating oils and less gasoline and kerosene.
3) The mixed base, which is an intermediate between I and II.

Crude oils are characterized by some physical and chemical properties, which to a measurable extent, play important role in the understanding of their geologic history and environment of origin. Such a physical property as optical activity is dependent on hydrocarbon derivaties from organic cholesterine substances, and are destroyed at high temperature of about 200^0 C. They serve as important criteria for environmental analysis, reconstruction of temperature history of the crudes, and correlation of crude oils. Cloud and pour points of crude oils reveal the influence of low temperatures on crude oils and simultaneously provide information about the paraffin wax content of the crudes. Most of the physical properties are influenced by the reservoir pressures and temperatures, chemical composition of the crudes, and sometimes, by the amount of dissolved natural gases.

The chemical properties of crude oils vary in relation to changes in geotemperatures and pressures, coupled with some other elements of katagenesis. Such chemical properties as paraffin wax and perhyrins are complex forms of hydrocarbons which have genetic relationship with living organic-life. Occurrence of isoprenoid hydrocarbons, such as pristanes and phytanes in crude oils, enhances the construction of the genetic environments of deposition of the source rocks. Trace metal substances concentrated in crudes are thought to be derived from sea water as secretions by marine life.

The economic significance of any crude is influenced by such properties as paraffin wax content, sulphur content and A.P.I gravity. Standard prices of crude oils are however fixed by producers like the Organization of Petroleum Exporting Countries (OPEC).

The A.P.I. gravities of Nigerian crudes change abruptly after a critical depth, where there is a marked change in temperature. Nigerian crudes are generally light, low sulphur-bearing, and are in great demand by advanced countries.

Some physical and chemical properties of crude oils have to some significant extent, given explanations to the genesis of crudes, and have provided information about the likely environments of deposition of the crudes source rocks. They also serve as correlation indices, and indicators of geologic age and alteration.

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Table 1: Classification of Crude Oils

Types of Crude	Wax %	Asphalt %	% Composition Of 200 – 300^0C Fraction		
			Paraffin	Naphthenes	Aromatic
Light Paraffinic	0 – 1.5	0 – 6.0	46 – 61	22 – 32	12 – 25
Paraffin-Naphthenic	1.0– 6.0	0 – 6	5 – 42	9 – 38	16 – 20
Naphthenic	trace	0 – 6	15 – 26	61 – 76	8 – 13
Aromatic	0 – 5.0	0 – 20	0 – 8	57 – 78	20 – 35

After Levinson, 1974

Table 2: Some properties of Nigerian crude oils

Bomu Oil Field (Onshore)	*Okan Oil Field (Offshore)*
Gravity: 34.4^0 API	Gravity: 34.6^0 API
Viscosity: 4.4 centipoises at 100^0F	Flash point: below 60^0F
Paraffin wax: 5.1%	Paraffin wax:
Sulphur: 0.16%	Sulphur: 0.15%
Pour point: + 64^{0+F}	Pour point: 25^0F
	Refractive Index: 1.4816
	Colour: Greenish brown
	Dissolved Natural: gases 3.56%
	C_6 + Heavier Hydrocarbons: 96.44%

(Source: Frankl and Cordry, 1967)

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