Geology. — *The potential energy of the gas in the oil bearing formations.* By J. VERSLUYS.

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Mineral oil accumulated in pools in the earth is as a rule saturated with gas at the prevailing pressure and in many cases some free gas is still found in the highest parts of the oil bearing anticlines and domes. If in some cases the oil was not saturated with gas at the initial pressure, the pressure would decline in the vicinity of the borehole as soon as the oil bearing stratum was struck and some oil and gas had escaped. On account of this some gas would be set free in the vicinity of the borehole and even the pressure of the edgewater would not re-establish the original pressure near the borehole, until all liberated gas had been dissolved again. So for some time the pressure observed would be approximately equal to that at which the oil would be saturated with the absorbed gas and this would be the pressure measured in the borehole.

If an oil has absorbed gas and afterwards the pressure is reduced a part of this gas can be set free and expand after it has been set free. Owing to this the gas is able to exert energy and this energy is supposed to yield the principal force expelling the oil from the porous rocks into the wells.

The object of this paper will be to find a mathematical expression for the extent of the potential energy present in this form. The work performed by the gas if it is set free and expands is supplied by the molecular energy and cooling would be the result. Assuming that the heat needed to restablish the initial temperature is supplied immediately we may accept that the process is isotherm and further we will disregard all deviations from the laws of BOYLE and HENRY.

Should a volume of oil q be under a pressure of p atmospheres and should it be saturated with gas at that pressure, the coefficient of absorption being a, that volume of oil would contain a quantity of gas, which would occupy at atmospheric pressure a volume

$$a q p \qquad (1)$$

If the pressure declines by dp a certain quantity of gas would be set free, occupying at the atmospheric pressure a volume

$$aq\, dp \qquad (2)$$

and at the pressure p under which the oil and gas are :

$$aq \frac{dp}{p} \qquad (3)$$

The volume of the oil and the gas associated with it, being q at the beginning, is increased by the volume expressed under (3). The work performed by the gas is then :

$$dA_1 = a\,\alpha q\,dp, \quad \ldots \ldots \ldots \quad (4)$$

if the pressure of one atmosphere equals a units of power per unit of area.

If the pressure declines from P_2 at which the oil is saturated with the gas it contains, to a pressure P_1, in this manner, i.e. at being set free, the gas will perform an amount of work :

$$A_1 = a\,\alpha q\,(P_2 - P_1) \quad \ldots \ldots \ldots \quad (5)$$

As the pressure decreases between those limits P_2 and P_1 the gas liberated while the pressure declined from p to $p—dp$ ($P_2 > p > p—dp > P_1$), will still expand owing to the pressure declining from $p—dp$ to P_1. The work performed by the quantity of gas, which would occupy the unit of volume at atmospheric pressure, should the pressure decline from p_2 to p_1 is:

$$a \log \frac{P_2}{P_1} \quad \ldots \ldots \ldots \ldots \quad (6)$$

according to a familiar formula.

Hence the quantity of gas set free between the limits of pressure p and $p—dp$ would, by expansion owing to the decline of pressure from $p—dp$ to P_2, perform work :

$$dA_2 = a\,\alpha q \log \frac{p}{P_1}\,dp \quad \ldots \ldots \ldots \quad (7)$$

The work performed by the expansion of the gas set free if the pressure declines from P_2 to P_1 is :

$$A_2 = a\,\alpha q \left\{ \int_{P_1}^{P_2} \log p\,dp - \log P_1 \int_{P_1}^{P_2} dp \right\} = a\,\alpha q \left\{ P_2 \log \frac{P_2}{P_1} - (P_2 - P_1) \right\}. \quad (8)$$

Hence, the total energy exerted by the gas, if the pressure declines from P_2 at which the oil is saturated to a smaller pressure P_1, is :

$$A = A_1 + A_2 = a\,\alpha q\,P_2 \log \frac{P_2}{P_1} \quad \ldots \ldots \quad (9)$$

The product $\alpha q\,P_2$ in this equation is the volume which would be occupied by all the gas originally absorbed in the oil at atmospheric pressure. If this volume be put at

$$\alpha q\,P_2 = Q_2 \quad \ldots \ldots \ldots \quad (10)$$

(9) becomes converted into :

$$A = a\,Q_2 \log \frac{P_2}{P_1}. \quad \ldots \ldots \ldots \quad (11)$$

A represents the energy which the gas being set free from the oil between the limits of pressure P_2 and P_1 exerts in two manners ; viz. owing to the liberation and owing to the expansion. We must keep in mind that the gas still remaining absorbed in the oil would at atmospheric pressure occupy a volume

$$Q_1 = aq\, P_1 \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (12)$$

and the gas set free between the limits of the pressure P_2 and P_1, would at atmospheric pressure occupy a volume :

$$aq\,(P_2 - P_1) = Q_2 - Q_1 \quad . \; . \; . \; . \; . \; . \quad (13)$$

Hence the energy expressed by (11) is exerted by a quantity of gas $Q_2 - Q_1$ in the two manners exposed above.

But the work expressed by (11) also equals the work which would be performed by a quantity of free gas Q_2 in expanding between the same limits of pressure P_2 and P_1 according to (6).

So we have deduced : if a volume of oil q at the pressure P_2 and P_1 $(P_2 > P_1)$ would be saturated by quantities of gas occupying volumes respectively Q_2 and Q_1, at atmospheric pressure, the volume of gas set free if the pressure after saturation declined from P_2 to P_1, would occupy a volume $Q_2 - Q_1$ at atmospheric pressure and this quantity of gas would during this process perform work equal to that performed by all the gas (Q_2) associated with the oil if it were free and expanded between the same limits of the pressure P_2 and P_1, this work being expressed by (11).

If the oil is — which often is the case in the highest parts of the structure — at the pressure P_1 not only associated with the quantity of gas Q_2, saturating it at this pressure, but also with a quantity of free gas, occupying a volume Q_f at the atmospheric pressure, this free gas would if the pressure declined from P_2 to P_1 exert an energy

$$a\, Q_f \log \frac{P_2}{P_1} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (14)$$

and the total work performed by the quantities of gas Q_2 and Q_1 would be

$$a\,(Q_2 + Q_b) \log \frac{P_2}{P_1} \quad . \; . \; . \; . \; . \; . \; . \; . \quad (15)$$

So in general for the work performed by all the gas (absorbed and free) associated with the oil in a pool if the *reservoir pressure ("rock-pressure")* P_r be smaller than or equal to the pressure at which the oil would be saturated with the gas present, may be written

$$aQ \log \frac{P_r}{P_o}, \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (16)$$

if P_o represents the pressure under which the oil and the gas leave the formation and Q the volume, all the gas, free and absorbed in the oil would occupy at atmospheric pressure.