reporting them; those given for the United Kingdom refer to 1959. Unfortunately, the wording used in these tables is not very lucid.

The following table is made up from data in the book. It has been prepared by placing the order of the countries according to the numbers of the larger farm animals: horses, cattle, camels and domestic water buffaloes; for the purposes of demonstration of animal wealth the smaller farm animals can be ignored. This table shows the enormous farm animal wealth of India, with more than double the numbers of any other country. It also brings out the very small numbers in many countries of great prominence.

Farm livestock (large animals) (millions)	Veterinary schools	No. of veterinarians	
207	16	5,583	India
96	18	20,861	United States
85	8	2,325	Brazil
83	23	x x x	U.S.S.R.
44	3	2,000	Argentina
32	3	508	Mexico
32	2	490	Pakistan
20	3	4,379	France
18	1	185	Kenya
17	1	1,262	Turkey

16	2	1,200	Australia
13	2	456	Colombia
13	4	8,297	German Federal Republic
12	1	430	Union of South Africa
11	1	109	Thailand
11	3	4,500	Poland
11	6	4,660	United Kingdom
10	2	2,000	Canada
10	9	7,700	Italy
9	1	56	Sudan
8	2	191	Indonesia
7	1	478	Iran
7	1	445	Uruguay
7	1	300	Venezuela
6	4	2,947	Yugoslavia
5	1	133*	Romania
4	2	2,050	Czechoslovakia
4	2	750	Ireland
3	1	1,076	Denmark
3	14	18,589	Japan
3	1	1,379	Netherlands
2	1	1,601	Austria
2	2	948	Belgium
2	1	x x x	Greece
2	1	2,550	Hungary
2	1	47	Iraq
1	1	896	Sweden
1	1	596	Norway
1	2	938	Switzerland
1	1	60	Viet Nam

* This figure would seem to be incorrect.
x x x No figure given.

W. A. POOL

NATURAL GAS IN THE NETHERLANDS

THE first natural gas field in Holland was discovered and developed by the N.V. Nederlandse Aardolie Maatschappij (N.A.M.) in 1948 in the province of Drenthe, at Coevorden. The gas-bearing formation is at a depth of more than 9,000 ft. Coevorden proved to be a small but exploitable field. Later, other small gas fields were discovered in the north-eastern provinces of Drenthe and Overijssel, also in the western province of South Holland, but the amount of gas available was relatively small, some 520,000 cubic yards per day, and at that rate a calculated twenty years' supply. In terms of energy this quantity of gas per day is equivalent to about 150,000 tons of coal per year; in 1954 the coal production of the Netherlands amounted to 12 million tons; thus the quantity of natural gas available in that year did not represent more than 1 per cent of the total coal production.

It was not until August 1959 that the natural gas situation was dramatically changed by the drilling of a well at Slochteren in the province of Groningen which proved the existence of an enormous gas-field, actually the third largest in the world, Panhandle, Texas, being the largest, followed by the Hassi R'Mel gas-field in the Sahara as second. After Slochteren No. 1 (as it was called), there followed successful strikes of gas at Delfzijl and Slochteren (No. 2) in 1960, at Ten Boer in 1961, at Nordbroek in 1962 and at Schildmeer in February 1963, all in the province of Groningen.

The total proved natural gas reserves in the Groningen province alone are so far estimated at some 520,000 million cubic yards, the largest in Europe. Compared with the French gas-field at Lacq in France, with estimated reserves of 230,000 million cubic yards, the Groningen field is more than double the size. A further factor is that the geographical spread of this natural gas deposit may not as yet have been completely determined; possibilities of extensions under the North Sea by off-shore drilling, equally eastwards into West Germany, are by no means unlikely.

Production from the Groningen region will be carried out by N.A.M., a joint venture of the Esso Petroleum and Shell Companies. N.A.M. and the State Mines Department of the Netherlands have formed a partnership "under which they will share the costs and the proceeds of the development of the natural gas on a basis of 60 and 40 per cent respectively". "... N.A.M. will deliver all the Groningen natural gas to a new company called N.V. Nederlandse Gasunie, which was formed on April 6 this year. Forty per cent of the new company is owned by the State Mines, 25 per cent each by Esso and Shell, and the remaining 10 per cent by the Dutch Government. Its function is to purchase, transport and market natural gas in the Netherlands". Further information on these extremely important developments is given in an illustrated article in a recent issue of *Esso Magazine* (12, No. 3; 1963).

H. B. MILNER

SEARCH FOR PETROLEUM IN AUSTRALIA

IN 1900 there was an accidental discovery of natural gas at Roma, some 300 miles west-north-west of Brisbane, Queensland. Since that time there have been many short-lived and unsuccessful attempts to locate oil and gas deposits in commercial quantities in that area. But prospecting for oil still continues with persistent enthusiasm and cautious confidence not only in this region but also in other potential places in Australia. As recently as 1959 the Commonwealth Government enacted the Petroleum Search Subsidy Act enabling exploration companies to carry out geophysical or bore-hole surveys for new sub-

surface stratigraphical information or in prospecting for petroleum. The Act provides for subsidy for the cost of operations subject to approval of projects by the Minister of National Development. On behalf of the Minister, the Bureau of Mineral Resources, Geology and Geophysics must examine and approve applications made under the Act, maintain surveillance of the operations and, in due course, publish the results. Thus has been provided a new stimulus in the time-long search for oil in this continent, and four publications recently issued by the Department of National Development (Bureau of Mineral Resources)

clearly demonstrate that the provisions of the 1959 Act are working in a most practical manner*.

Publication No. 8 deals with Frome Rocks No. 1 and No. 2 Wells, located about 100 miles east-south-east of Broome on the north-west coast of Western Australia, the operations being carried out by West Australian Petroleum Pty., Ltd., No. 1 penetrated 734 ft. of Recent deposits, thence through normal Jurassic sequence to the Frome Rocks Salt Dome. No signs of hydrocarbons were seen. No. 2 was drilled to more than 7,500 ft., but results were not significant. This area does not appear very promising.

Publication No. 35 takes us back to Roma once again; it deals with the East Roma Seismic Survey, carried out in 1959-60 by Austral Geo Prospectors Pty., Ltd., on behalf of Associated Australian Oilfields N.L. The conclusion is reached: "The complex geology of the East Roma area is such that there are a multitude of positions

which are favourable for the accumulation of oil and gas. . . . The East Roma area should be given first priority for continued drilling and further seismic exploration programmes. It seems certain that there is gas in commercial quantities".

Publication No. 36 describes the Blue Hills-Logue Seismic Survey, Western Australia, also made in 1959-60 by West Australian Petroleum Pty., Ltd. The survey area is some 50 miles south-east of Broome. The results clarify the delineation of known anticlinal structures in this area, but petroleum prospects are so far not disclosed.

Publication No. 39 concerns the Longreach-Silsoe Seismic Survey, Queensland, carried out by Cree Oil of Canada, Ltd., in 1960. This again resulted in fresh structural interpretations in this area, but beyond some oil and gas at certain horizons previously known, there appears to be little encouragement to anticipate commercially valuable petroleum deposits here.

Despite all these results, however, the search for oil and gas still proceeds in Australia, and if the vast gas-fields of the Netherlands and the Sahara (traditionally considered unlikely regions for hydrocarbon accumulations in commercial quantity) are anything to go by, then there is ample reason for prosecuting that search.

H. B. MILNER

* Commonwealth of Australia: Department of National Development, Bureau of Mineral Resources, Geology and Geophysics. Publication No. 8: *Frome Rocks No. 1 and No. 2 Wells, Western Australia of West Australian Petroleum Pty., Limited.* Pp. 55+4 plates. Publication No. 35: *East Roma Seismic Survey, Queensland, 1959-1960, by Associated Australian Oilfields N.L.* Pp. 18+6 plates. Publication No. 36: *Blue Hills-Logue Seismic Survey, Western Australia, 1959-1960, by West Australian Petroleum Pty., Limited.* Pp. 24+3 plates. Publication No. 39: *Longreach-Silsoe Seismic Survey, Queensland, 1960, by Cree Oil of Canada Limited.* Pp. 10+5 plates. (Canberra: Department of National Development, Bureau of Mineral Resources, Geology and Geophysics, 1962.)

DETERMINATION OF THE NON-ZONAL HARMONICS OF THE GEOPOTENTIAL FROM SATELLITE DOPPLER DATA

By DR. W. H. GUIER

Applied Physics Laboratory, Johns Hopkins University, Silver Spring, Maryland

A LEAST squares determination of values for the coefficients, C_n^m , S_n^m , of the non-zonal harmonics of the geopotential:

$$U(r, \varphi, \lambda) = \frac{K}{r} \left\{ 1 + \sum_{n=2}^{\infty} \sum_{m=0}^n \frac{P_n^m(\sin \varphi)}{r^n} [C_n^m \cos m\lambda + S_n^m \sin m\lambda] \right\} \quad (1)$$

has been made through $n=m=4$ using Doppler data from the three Satellites 1961 $\alpha 1$, 1961 $\alpha 71$, and 1962 $\beta 1$. In equation (1):

r =geocentric radius from the Earth's centre of gravity;
 φ =geocentric latitude; λ =geocentric longitude from Greenwich meridian,

and $P_n^m(z)$ are the associated Legendre polynomials:

$$P_n^m(z) = (1-z^2)^{\frac{m}{2}} \frac{d^m}{dz^m} P_n(z) \quad (2)$$

The values of C_2^2 and S_2^2 were constrained to be identically zero in the determination.

Table 1 presents a brief summary of the Doppler data which were chosen for the determination. The data were chosen as being the best available from the point of view of: (1) quality with respect to noise-level, timing errors, presence of ionospheric refraction errors, and stability of the satellites' transmitted frequencies; (2) uniform distribution of station locations over the Earth's surface with particular care taken to avoid an overweight of data from stations located within the continental United States; (3) uniform coverage of the satellite orbit by the data with respect to the angle between the ascending node and the Greenwich meridian.

The principal ionospheric refraction contribution was removed by coherently combining two frequencies received simultaneously from the satellite in the Doppler receiving equipment^{1,2}. To ensure further minimum refraction errors, data were considered only if the maximum elevation of the pass was less than 83° and greater than 20°. Finally, data points which corresponded to instantaneous elevations below 13° were deleted, and the remaining data points corrected for tropospheric refraction³. A typical noise-level for that data finally chosen was roughly 5 parts in 10¹⁰ of the transmitted frequency. Timing errors were judged to be below 0.003 sec (3-sigma value).

The data which survived the foregoing criteria were then grouped by days, one group containing all passes for a given satellite which occurred between two successive midnights (G.M.T.). After grouping, only those were selected which contained ten or more high-quality sets of data from at least five separate stations with at least three being outside the continental United States. From Table 1 it can be seen that the fewest groups of data for any one satellite occurred for Satellite 1961 $\alpha 71$. This is due to the low inclination of the satellite precluding reception of data from high-latitude stations. While considerably more groups of data satisfying the foregoing criteria were available for the other two satellites, the total number of groups chosen for each satellite was limited to being roughly equal to avoid overweighting the data corresponding to a particular inclination. In the final choice of groups care was taken to ensure a reasonably even distribution of angles between the ascending node and the Greenwich meridian at the time of the first pass in each group. In addition, groups for two different satellites occurring on the same day were avoided to increase the *a priori* probability that the effects of undetected station instrumentation errors and refraction errors were random.