A SLIM-HOLE NEUTRON ACCELERATOR FOR MULTIPURPOSE APPLICATION

Sideris,G.N.* and Buckup,K.**

* Institute of Geology and Mineral Exploration, Department of Geophysical Exploration, 70 Messoghion Ave., Athens 11527, Greece.
** "Der Bohrlochmesser", Spielhagenstr. 91, 0-3031 Magdeburg, Germany.

A B S T R A C T

Pulse-neutron methods may be used for many different practical tasks. In view of the lack of radioactive pollution the method has advantages above the actual widely practiced stationary neutron methods.

A newly developed tool, by "Der Bohrlochmesser", with an outer diameter of 42mm allows for adaptation to any digital logging equipment. The neutron tube emits more than 10^8 n/s. Examples from hydrological wells, gas-fields and underground natural gas storage-facilities show the practicality of the method. Technical data and geophysical borehole logging results are demonstrated.

ΕΝΑΣ ΕΠΙΤΑΧΥΝΤΗΣ ΝΕΤΡΟΝΙΩΝ ΠΟΛΛΑΠΛΩΝ ΓΕΩΕΠΙΣΤΗΜΟΝΙΚΩΝ ΕΦΑΡΜΟΓΩΝ, ΓΙΑ ΧΡΗΣΗ ΣΕ ΓΕΩΤΡΗΣΕΙΣ ΜΙΚΡΗΣ ΔΙΑΜΕΤΡΟΥ

Σίδερης,Γ.Ν. και Buckup,K.

Π Ε Ρ Ι Λ Η Ψ Η

Μέθοδοι εκπομπής παλμών-νετρονίων μπορεί να έχουν προοπτική για πολλές, διαφορετικής φύσεως, γεωεπιστημονικές εφαρμογές. Με την εφαρμογή αυτής της μεθόδου αποφεύγουμε τη ραδιομόλυνση και επιτυγχάνουμε σημαντικά οφέλη σε σχέση με τις ήδη γνωστές στατικές μεδόδους νετρονίων.

Αναπτύχθηκε ένας σύγχρονος φωρατής, με εξωτερική διάμετρο 42 mm., ο οποίος επιτρέπει την προσαρμογή και λειτουργία του σε οποιοδήποτε ψηφιακό συγκρότημα διαγραφιών γεωτρήσεων. Η λυχνία νετρονίων εκπέμπει περισσότερα απο 10^8 νετρόνια/δευτερόλεπτο. Μετρήσεις σε γεωτρήσεις υδρογεωλογίας, κοιτασμάτων αερίων, και χώρους αποθήκευσης αερίων, δείχνουν την αποτελεσματικότητα της μεθόδου. Παρουσιάζονται ακόμα τεχνικά στοιχεία και αποτελέσματα μετρήσεων σε γεωτρήσεις.

INTRODUCTION

Standard neutron measurements suffer, mainly, from three draw backs:

1. Application of stationery neutron sources with the danger of radioactive pollution and difficulties on exposure control.
2. Widespread neutron energy distribution along the whole

spectrum.
3. Dominance of low-energy neutrons and a small neutron output.

Therefore neutron methods did not find the due application in flat wells for hydrogeological (Buckley and Oliver, 1990), ecological and engineering purposes.

A new developed two-channel pulse-neutron-tool, by "Der Bohrlochmesser", deals with these problems and was designed for universal application under different geopractical conditions.

TECHNICAL PARAMETERS

The new tool includes the following basic electronic groups, fig.1 :

1. Neutron-accelerator.
2. Detector section.
3. Magnifier-converter.
4. Programmable analyser.
5. Buffer memory.
6. Power supply.
7. Controller unit.
8. Interface.

The outer diameter (O.D.) is 42 mm and will therefore suit a large range of borehole diameters above 50 mm. The tool is rated for 120°C and 120 Mpa. The overall length, depending on configuration, does not exceed 4000 mm. The neutron energy equals 14 MeV, the neutron output is above 10^8 n/s, and the minimum

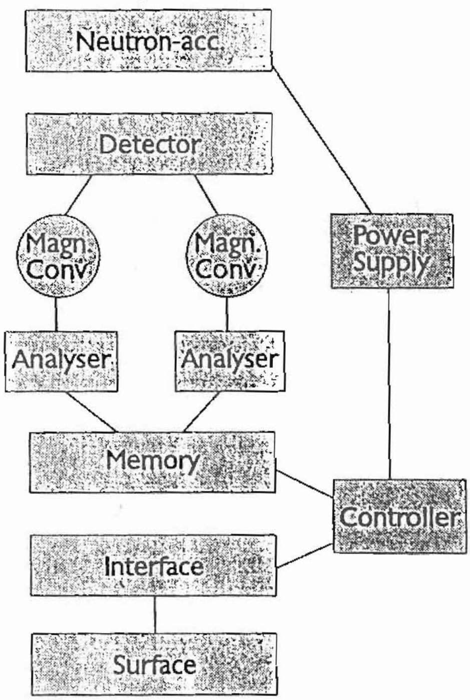

Fig.1. Principal scheme of the neutron accelarator.

lifetime of the neutron tube exceeds 35 working hours. The interface allows an adaption to any type of digital or computerized logging units. The detector and the transmitter sections are built-up as exchangeable modules, that allow an on-spot-change of the accelerator after burning-down or a modification for recording the gamma-rays.

The tool corresponds to two working frequencies, i.e. 10 and 20 Hz, so that the logging speed can be increased twice without loosing accuracy. The probe is powered by 220 Volt supply at a frequency of 400 Hz. The spacings for the two channels are: L^1 = 38 cm, and L^2 = 63 cm.

Pulses may be recorded in time-windows from 0 till 1600 μs, in 30 μs-intervals, that provides the facility to carry out a time-based neutron-sondage.

An associated software allows the recording of pulse-rates for each chosen window at a pre-given time-delay.

TECHNOLOGICAL FACILITIES

By the two-channel lay-out and the time selectable counting windows, a neutron-sondage of the borehole may be achieved, fig.3. If the counting rate is sufficient, the resulting picture is helpfull in determining the necessary logging parameters for eliminating the borehole influence. In the case of Fig.2. a

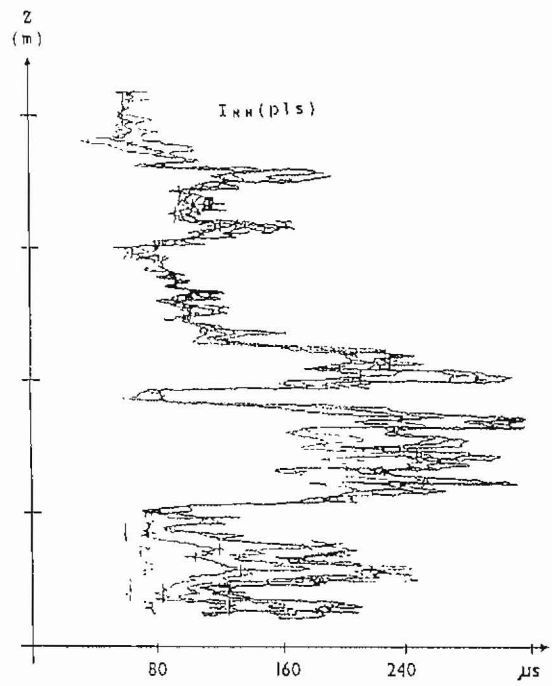

Fig.2. Neutron sondage.

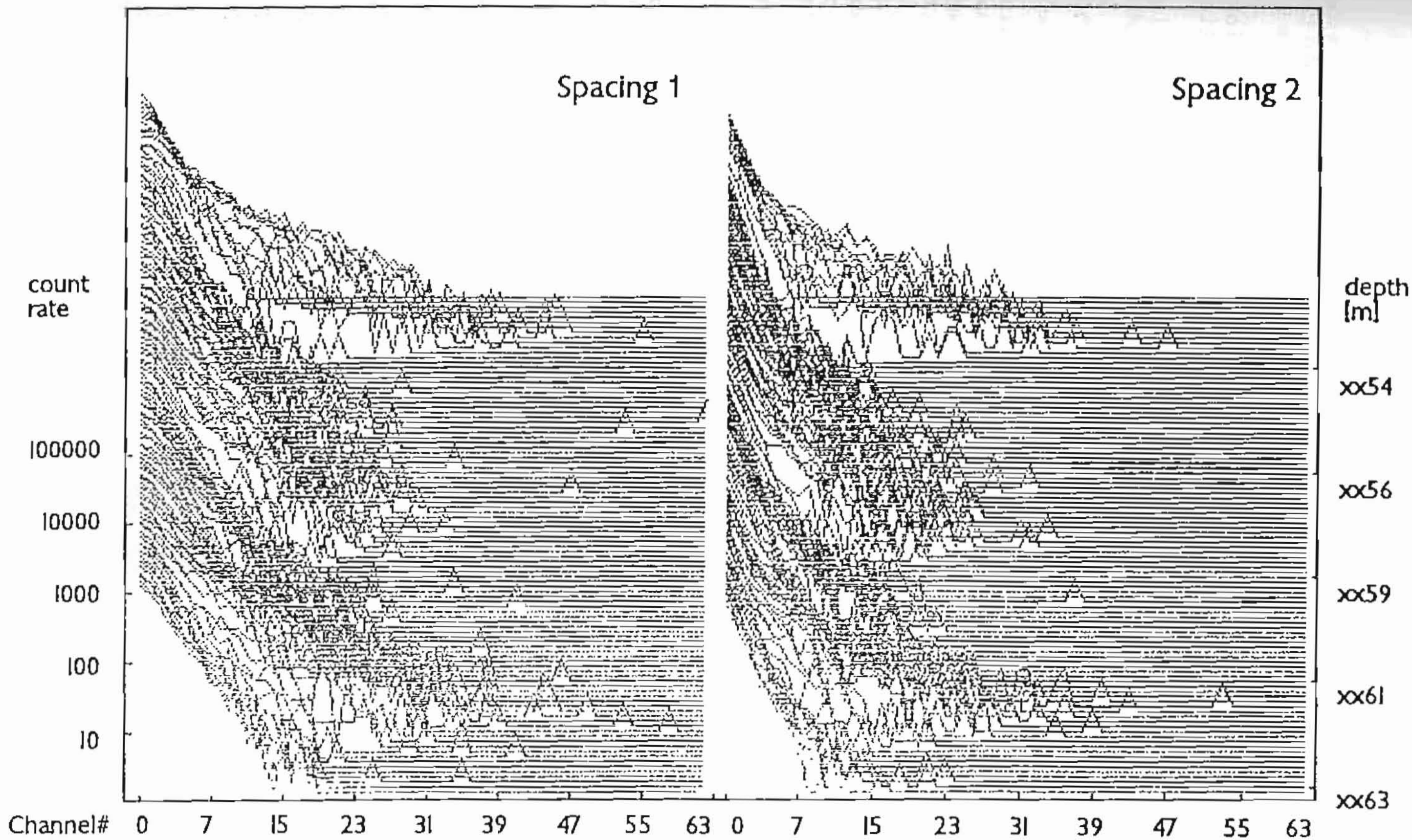

Fig.3. A 3-D presentation of the neutron-response.

time-delay of 400 μs provides that effect.

Controlling the delay and the window-width allows us to obtain a time-spectrum for the zones of interest. From fig.3, the advantages of that approach seems to be clear. The appearance of "unusual" pulses in late channels signifies the presence of material different from the mineral content of the formation, which may be related either to mineral concentration (Wylie, 1984) or to artificial pollution.

The tool construction allows the recording of all arriving pulses, only dead-time-breaks of about 30 μs must be taken into account, therefore the window-width can not be smaller than 30 μs, but any bigger width is possible. That, on the other hand, provides an accumulation of pulses for better statistics in high-number-channels.

The logging result is a pulse rate for a selected depending window/delay-combination (Knoll, 1979). All other parameters may be calculated, in accordance with the geological task. Parameters like, any selected ratio, sigma or the lifetime coefficient i, are beside the counting rate. For i, software-based approaches are available for the transformation into geologically relevant parameters. The tool construction allows adaptation to any digital or computerized recording device by a 19", mountable controlled, board and the corresponding software package.

SOME THEORETICAL ASPECTS

The neutron lifetime coefficient i may be calculated for each chosen depth point, on the basis of the relation time/pulse rate (see fig.2). The quantity i is related, methodically, to different geological parameters.

For the sample of fig. 6 the procedure is demonstrated on fig.7 to transform i into saturation values.

The transformation is carried out using the following basic formula:

$$\Sigma = \Sigma B(1-p) + \Sigma_W S_W p + \Sigma_G S_G p$$

for a 3-component model, where:

- Σ - macroscopic cross-section
- p - porosity
- S - saturation
- B, W, G - stand for bulk, water and gas.

The discussed sandstone interval of fig.6 delivers saturation values SG of about 50% and must be treated as gas-bearing.

COMPARISON OF LOGGING RESULTS

The new tool has already been tested under different conditions in the field (Buckup and Sideris, 1992). In fig. 4, a sample is shown from a fluid storage facility. For this exploration application, it was required to establish the level of the blocking medium in the annulus. By a rapid changing of the pulse rate the level was found at 87.5 m. Standard neutron methods are not responding.

In the case of fig. 5 for a shaly-sand-sequence it was

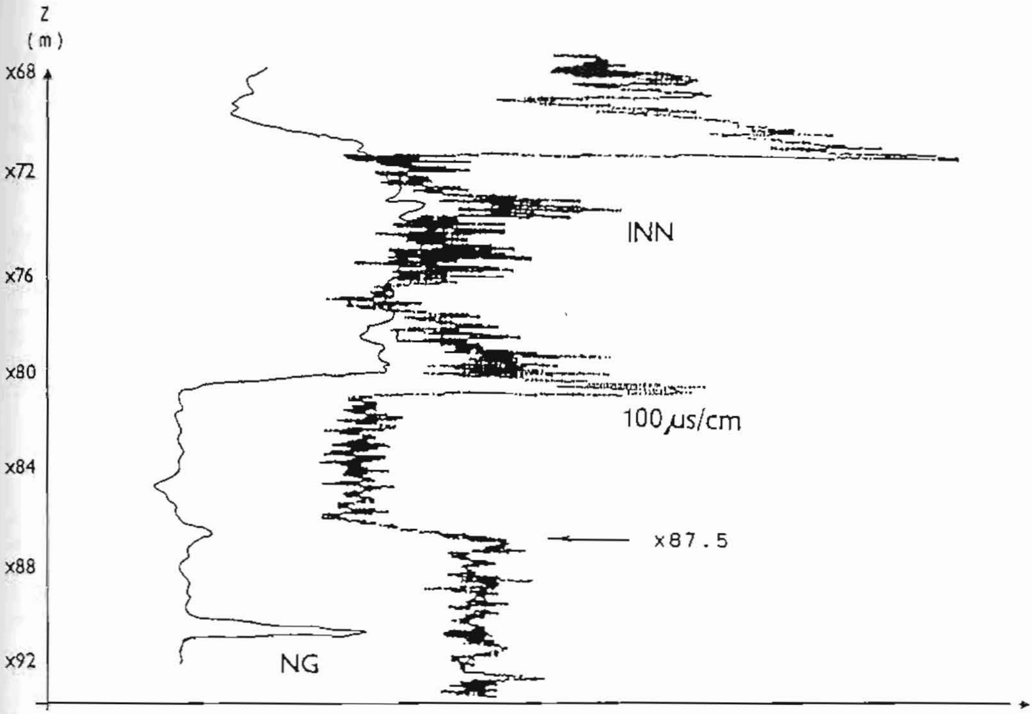

Fig.4. Pulse-neutron-record from a fluid storage facility.

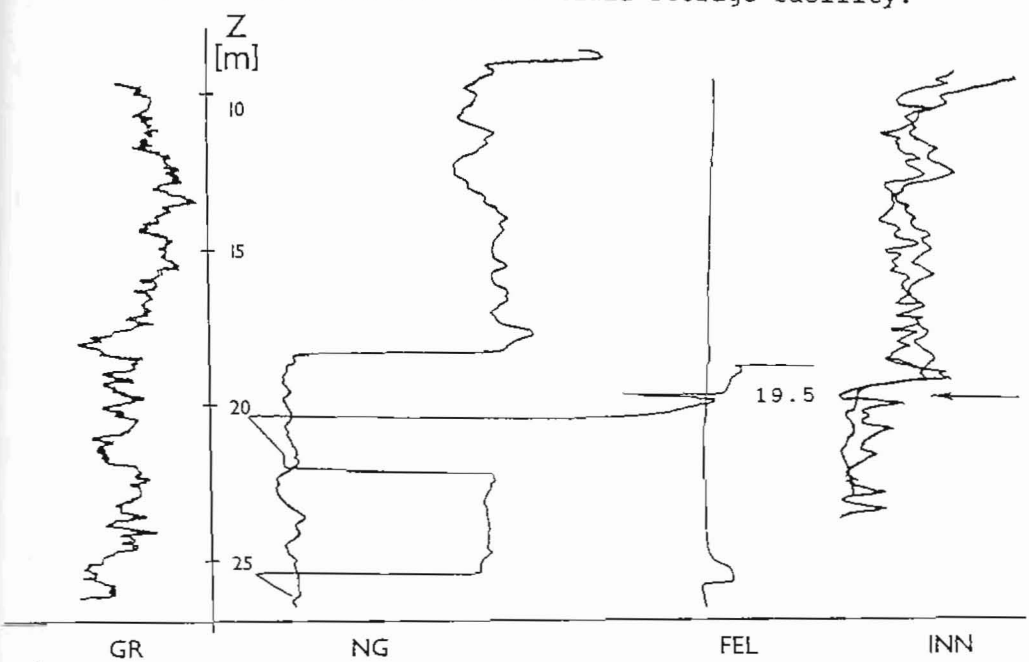

Fig.5. Sample from a shale-sand-sequence.

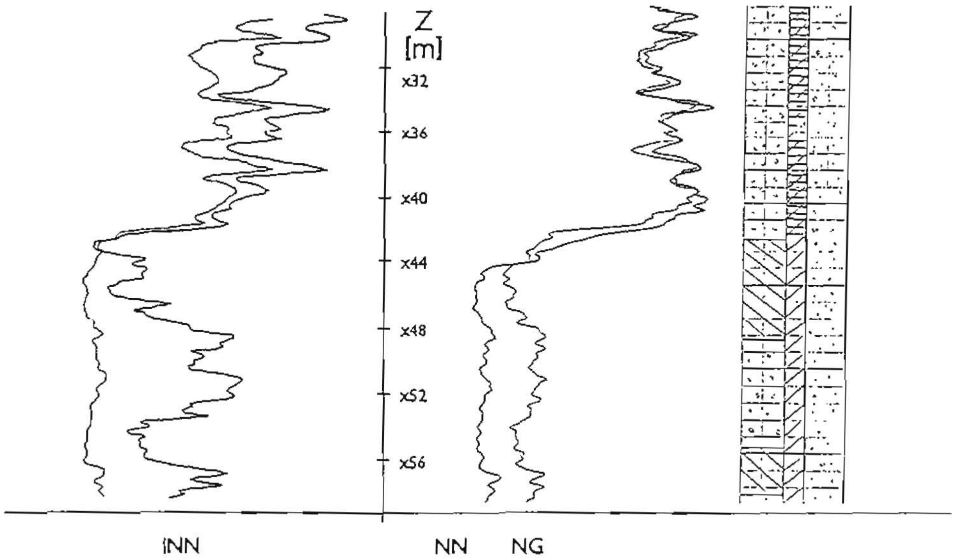

Fig.6. Application of INN for lithological differentiation.

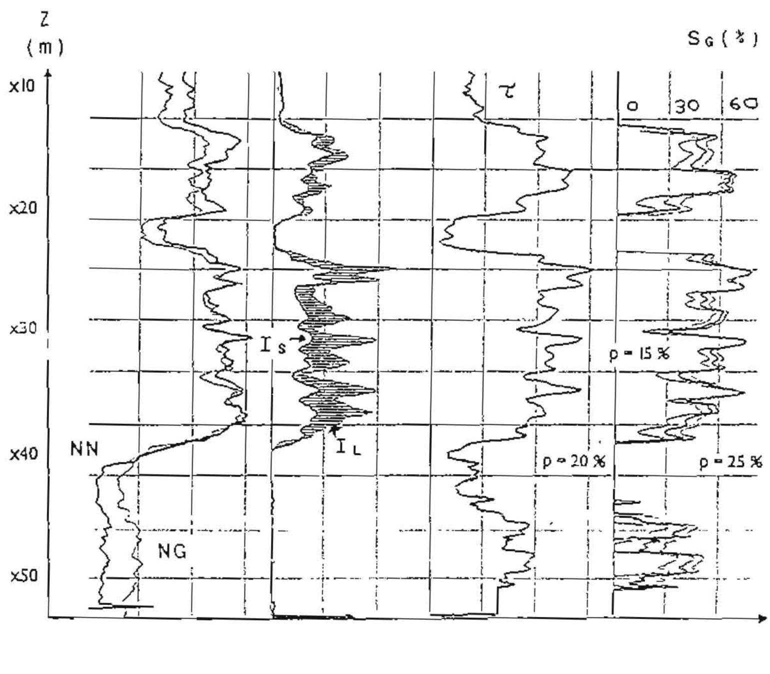

Fig.7. Sample for a S_G-calculation from INN.

required to find the interval of a catastrophic fluid loss. The pulse-neutron-method delivered an indication at the depth of 19,5 m. By the help of a pumping test, later on, that was confirmed. This depth interval is characterized by a high degree of "dry" fractures and therefore causes the fluid loss, and again no standard method was applicable.

In fig. 6 an example is given for the lithological determination, by the pulse-neutron-method.

The quiet indifferent interval of the standard neutron measurements between 638 and 655 m. appears very differentiated on the pulse-neutron-log. According to geological description, the horizon is made up of sandstone. For the exploration of this underground gas storage facility the conclusion was very important and fits into the overall geological understanding.

CONCLUSION

A slim-hole neutron accelerator for pulse-neutron measurements has been developed. It uses a unique pulse accumulating system,providing sufficient pulse-rates to run neutron log under different geopractical conditions. The first tests proved a multipurpose applicability for fluid and gas storage facilities, and also for flat wells.

Standard theoretical approaches allow us to make quantitative saturation calculations, excluding the borehole influence, by the means of technological properties via time-depending analysis of the recorded pulses.

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Code for symbols used in the Text and in the Figures.

GR : Gamma-ray.
NG : Neutron Gamma.
NN : Neutron-Neutron.
FEL : Focused Electrical Log.
INN : Impulse Neutron-Neutron.
SG : Gas Saturation.
τ : Lifetime.
IS : Impulse short.
IL : Impulse long.