

Fiscal review finds UK generous to a fault

The UK is regarded as an anomaly in terms of its fiscal regime for oil exploration and production, according to Geneva-based petroconsultants in its Annual Review of Petroleum Fiscal Regimes (RFR), which analyses 101 examples worldwide on a broad range of hypothetical oil field developments ranging from 'marginal' to 'upside' developments.

The review suggests that while a number of companies have made their terms more attractive in the past year, the UK continues to stand out as offering potential investors the lion's share of any economic rent generated by oil developments (67% on a discounted basis) and still opening up attractive exploration acreage.

In its comparison of countries, the review picks out Venezuela as more typical of the 'high prospectivity: high state stake' approach adopted by most countries. Over 85% of profits generated by any project will go to the state coffers if the new fiscal regime in Venezuela is confirmed for the first licensing round in the country since 1975. Similar state takes can be seen in Colombia, Egypt, Indonesia, Malaysia and Norway while at the other end of the scale, other than the UK, the main countries are Ireland, Equatorial Guinea, Spain, Paraguay and Turkey, none

of which are particularly prospective. The review notes that in Russia and the CIS states production sharing contracts are becoming increasingly common although the legality of such contracts and the applicability of multifarious taxes remains steeped in uncertainty.

Last year a number of countries moved to change their fiscal regime approach in terms of their perception of the balance of risks and potential rewards. Cost recovery ceilings and profit shares available to investors significantly increased in Albania and Yemen and 'frontier' terms were established in Angola, Gabon, Indonesia,

Malaysia and Nigeria, the country which most conspicuously softened its fiscal regime for very deep water projects.

Petroconsultants warn that most fiscal regimes continue to be regressive and have the potential to deter development. Colombia was noticeable in its attempt to increase the state take in new discoveries, although the policy may yet backfire as a result of industry hostility to its proposals. New Zealand, Egypt and Syria are mentioned as three countries where the fiscal regime may deter the industry.

West of Britain study in prospect

All the acreage in UK and Irish waters West of Britain from the Faeroes and West of Shetland to the South West Approaches has been the subject of a new study by UK companies Exploration Geosciences and ARK Geophysics.

Available at the end of this month the study, described by the companies as innovative, comprises a full structural interpretation and a comparison of all basins

including a review of stratigraphy, petroleum geology and play concepts. It is presented in the form of an atlas with 11 montages with all maps prepared at 1:1000 000 scale. The companies say that the study is the first of its type as the area has traditionally been broken down by basin. The atlas is intended to provide a full regional picture and addresses the structural evolution of the NE margin of the Atlantic.

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Software designed to go places

The geophysical project management consulting firm and software developer Houston Geoscan deserve some sort of prize for the ingenuity put into naming its latest product which has been christened PLACES which stands for Professional Land Acquisition Control and Evaluation System.

Behind the acronym is software developed to enable the input, management and retrieval of daily results, production and observations in response to a poll of potential users from management and field personnel. Designed in a Windows environment the user is able to input data from field notes, from data collectors or from SEG P. 3 and output to Mesa as well as standard and non-standard formats including user definable. According to Houston Geoscan, pre-plotting, plotting and mapping utilities are included to allow the importing of digital orthographic maps, digital elevation maps and digital topographical maps. It also supplies SEG-Y and SEG-D headers containing position data and is able to import any X, Y, Z ASCII file with common record length. In addition PLACES allows graphical analysis of data on the fly.

The software package is modular and includes SURVEY MANAGER, CONVENTIONAL SURVEY ANALYST and GPS SURVEY ANALYST modules.

IT outsourcing at BP in Aberdeen

BP Exploration in Aberdeen is to outsource its data management and cartography services using the Schlumberger company GeoQuest as its prime contractor.

today's oil industry.

GeoQuest has expanded its Aberdeen task to take on the new project and has added specialists from the information technology industry and from BP. All functions except the service desks will be provided by GeoQuest in Aberdeen via a high-speed communications link.

According to Magne Sveen, GeoQuest's European manager, the company regards the contract as a validation of its strategy to create a broader range of services for its clients. He noted 'Information Technology services were established to focus on the increasing need of oil and gas companies to outsource some or all of their non-core functions. Outsourcing these requirements allows management to concentrate on activities that contribute directly to the bottom line.'

Visualization software for reservoir simulator

A visualization package from the Abingdon, UK office of Intera Information Technologies has been chosen by Shell International Petroleum Maatschappij (SIPM) for visualizing reservoir models generated by its proprietary MoReS simulator. The software InteraView has been interfaced to MoReS and distributed to Shell operating companies worldwide.

Criteria of particular importance to Shell in its review and selection of visualization package were features such as the display of arbitrary XYZ planes through the model, the ability to display isosurfaces, 'pop up' well plots, the ability to view MoReS models directly without necessity for data conversion.

Update for log archiving

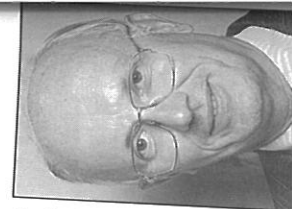
An update (version 1.2) of the compact log archiving software package LOGDB has been released by Schlumberger company GeoQuest. The product is designed to accommodate a wide variety of log data logging companies which is used to E&P companies to access their corporate assets effectively.

LOGDB, which is said to be installed in major oil companies worldwide, is capable of cataloguing, storing, validating and retrieving ever larger volumes of log data needed through the life cycle of a well. The system recognizes types of data should be on well logs, prompts for mandatory entry of missing data, quality checks current and automatically superimposes corrections for user approval.

Ken Landgren, GeoQuest's market manager for data management products said the LOGDB allowed geoscientists to export quickly their data to project databases for interpretation applications. LOGDB can also be integrated directly with corporate databases.

People in the News

A change at the top of Compagnie Générale de Géophysique (CGG) has been marked by the appointment of Yves Lesage as chairman and CEO. Lesage's career has up to now

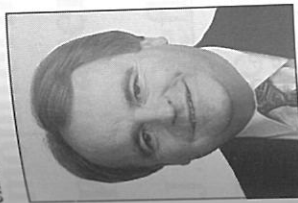


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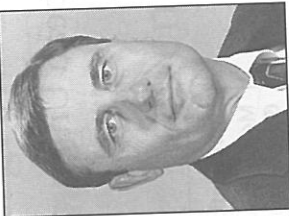
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Olof Lundberg, director general of Inmarsat since its creation in 1979 is to be chief executive officer of an affiliated



Robert Brunk



Will Forest

time consultant with Applegate Associates, Golden, Colorado, USA. Prof. Applegate will continue to operate his consulting practice.

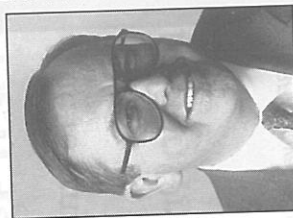
Hydro Projects with offices in Great Yarmouth, Aberdeen and Stavanger has appointed **John Harries**, ex chief surveyor with Amoco (UK) Exploration as company chief surveyor and

Brian Wilkins, ex chief surveyor of Conoco UK, as consultant project manager.

Joe M. Evon, previously group general manager of the Australia division, has been appointed president and general manager, BHP Petroleum, Europe, Russia, Africa and the Middle East.

Carl H. Savit, retired senior vice presi-

dent, Western Geophysical, has been elected to the US National Academy of Engineering for 'advancing technology of geophysical exploration and providing leadership within the larger social and environmental context.' The same honour has also gone to **Steven J. Wallach** of Convex Computers in recognition of 'the creation of system approaches leading to affordable supercomputers'.



Joe M. Evon

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Microseismic surveying and repeated VSPs for monitoring an underground gas storage reservoir using permanent geophones¹

J.P. Deflandre², J. Laurent², D. Michon³ and E. Blondin⁴

Introduction

This article deals with the recent development of permanent downhole geophones and their use for both passive and active monitoring of an underground gas storage reservoir. This was part of a joint research project in which Compagnie Générale de Géophysique (CGG), ELF Aquitaine Production (EAP), Gaz de France (GDF), Institut Français du Pétrole (IFP) and TOTAL were associated. The aim of this project was to develop and test 3-component permanent sensors.

The concept of permanent sensors was proposed for time-lapse seismic applications but also has application for acoustic monitoring. Both these types of observation have been carried out with a set of three permanent sensors placed in the same well in an underground gas storage facility belonging to GDF and located at Germigny-sous-Coulombs (Paris Basin, France).

Seismic monitoring with data collected at the surface or with buried geophones has been used for the monitoring of waterflooding (Dunlop *et al.* 1991), of gas front movement (Blondin *et al.* 1986; Blondin and Mari 1986; Johnstad *et al.* 1993), and of thermal EOR processes (Wayland and Lee 1986).

Permanent sea-bottom geophones have been used for monitoring an underground gas flow (Kolbjørnsen *et al.* 1991).

Several experiments have already been carried out with geophones cemented in holes specifically drilled for the

pore pressure decrease, resulting in microseismicity (Segall 1989; Grasso *et al.* 1992). Different mechanisms can result from the modification of effective stresses due to pore pressure variations:

- tensile or shear failures depending on the mechanical equilibrium involved and the rock properties;
- fault displacement.

These phenomena can result from production, i.e. depletion, but also from well or reservoir stimulation such as hydraulic fracturing and water injection. Therefore, studying the microseismicity associated with reservoir exploitation contributes to a better characterization of a reservoir's mechanical behaviour. The primary application is to hydraulic fracturing where fracture mapping can be performed (Albright and Pearson 1980; Talebi *et al.* 1991; Stewart *et al.* 1992; Deflandre and Sarda 1994). In this case the azimuth of the mean *in-situ* stress can be evaluated on the basis of measurements which are not limited to the wellbore. In the case of gas storage the pore pressure is greater than the hydrostatic pressure during injection and can be less than hydrostatic during withdrawal. Such a pattern occurs every year and is equivalent to a cyclic mechanical stress pattern on the reservoir which is initially poorly consolidated in our case (Sarda *et al.* 1993).

The target was to obtain a better reservoir description, particularly of the gas saturation in the different layers, by combining the interpretation of time-lapse seismic

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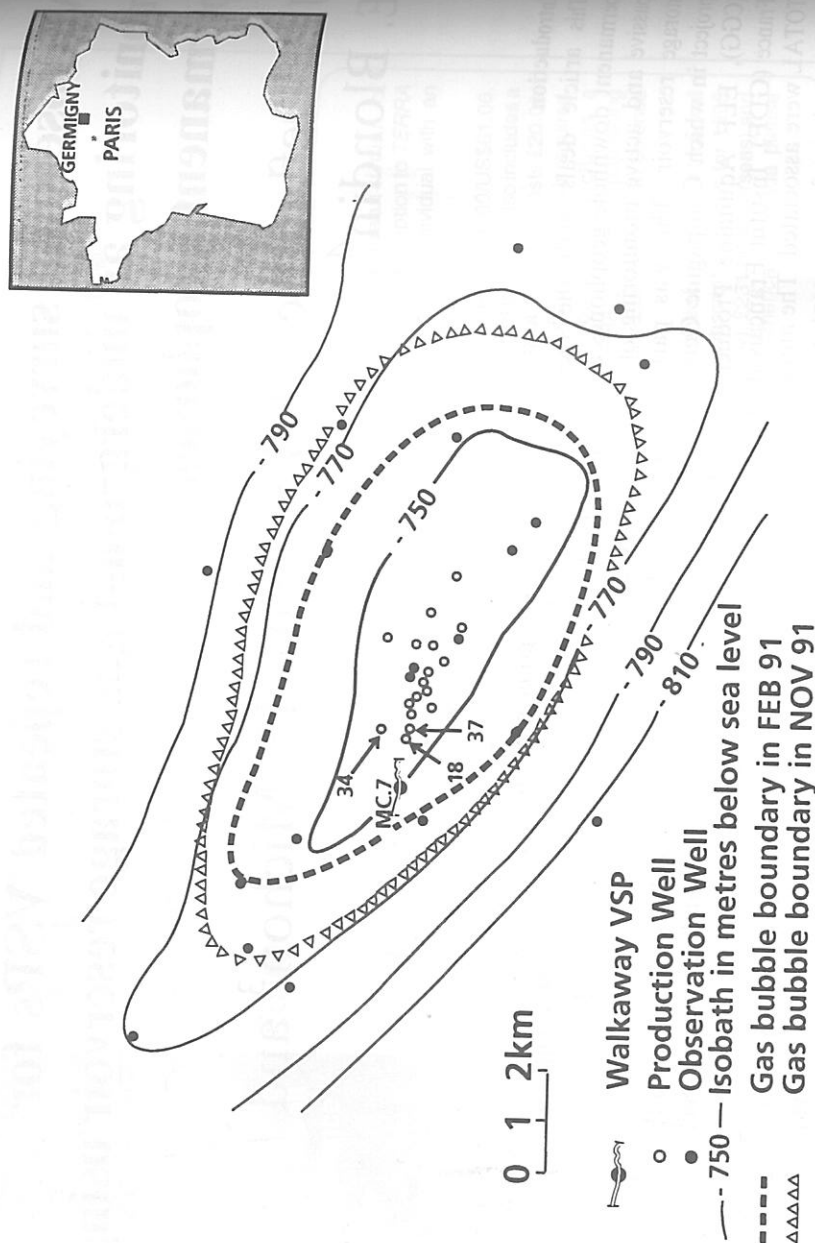
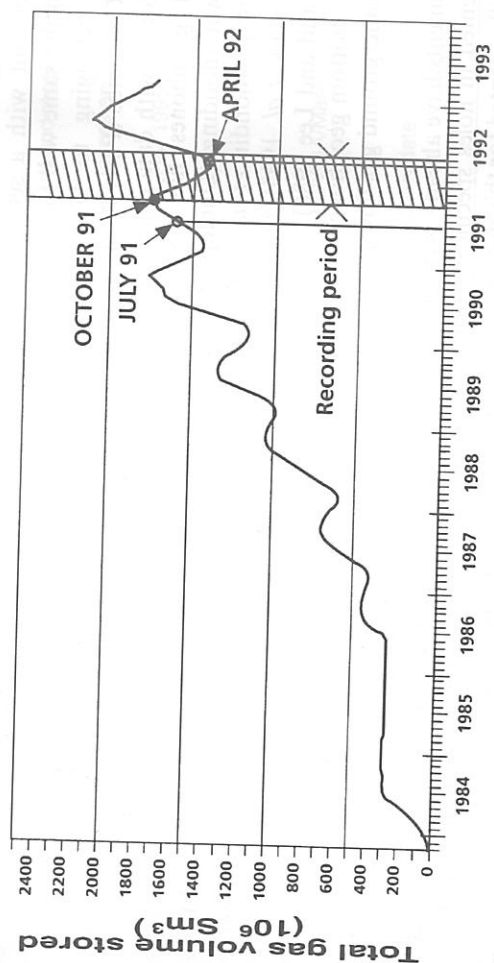


Fig. 1. Germigny-sous-Coulombs gas storage facility. Map of the isobaths of the Wealden reservoir top. Location of well MC7 and of the walkaway VSP line, and extent of the gas bubble in February and November 1991 are shown. Wells Nos 18, 34 and 37 are located 1.3 to 1.7 km from well MC7.



any increase. Figure 3 shows gas saturations in the different layers as they were measured in July 1991 by using a neutron log. The gas was mainly located in reservoirs R1 and R3 with some gas shows in reservoir R2. Above the upper aquifer there is a series of layers including Barremian sandy shales, shaly sands, etc. Below the reservoir there are limestone layers.

The observation well MC7 (see Fig. 1 for its location) was chosen to be equipped with the sondes. This well is used to monitor the gas saturation in the different reservoir layers by neutron log recordings. Like all the wells on the site, it was safeguarded against corrosion by using cathodic protection. Three on-tubing sondes were run into the well. Sonde 1 was set at 905 m depth just below the reservoir, and the other two sondes were set above the reservoir, at 815 m and 783 m, respectively (Figs 3 and 4).

Permanent geophones

Two types of permanent sensors have been developed: the behind-casing sonde (see Talebi *et al.* 1991) and the on-tubing sonde. These two types make it possible to satisfy different conditions of well completion. Only on-tubing sondes were used in the experiment described in this article. The diagram in Fig. 4(a) shows the string of permanent geophones placed in well MC7. Three

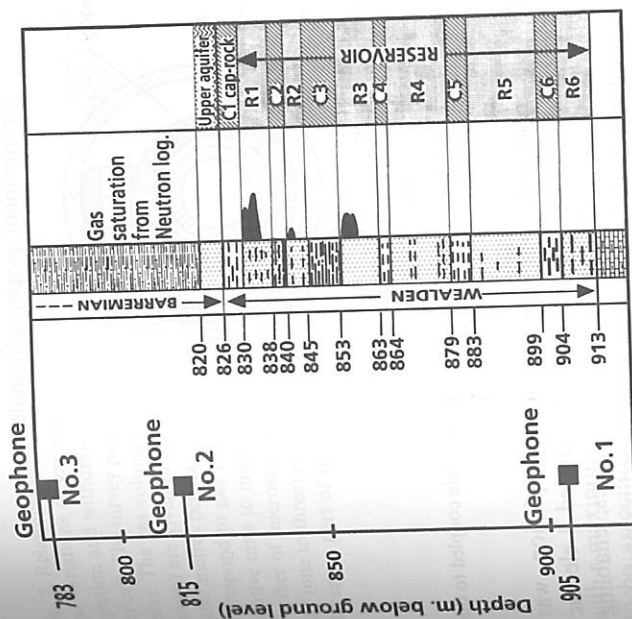


Fig. 3. Partial lithologic log of well MC7 with the location of the three permanent geophones: above the gas-saturated reservoir (No. 2 and No. 3) and at its base (No. 1). The reservoir includes porous and permeable levels (R1 to R6) and shaly intercalations making up intermediate cap rocks. Main cap rock C1 is directly overlain by the upper aquifer, which itself is overlain by alternating shale and shaly levels. The neutron log curve recorded in July 1991 shows some gas saturation in R1 and R3 and some gas shows in R2.

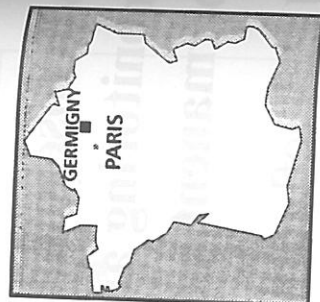
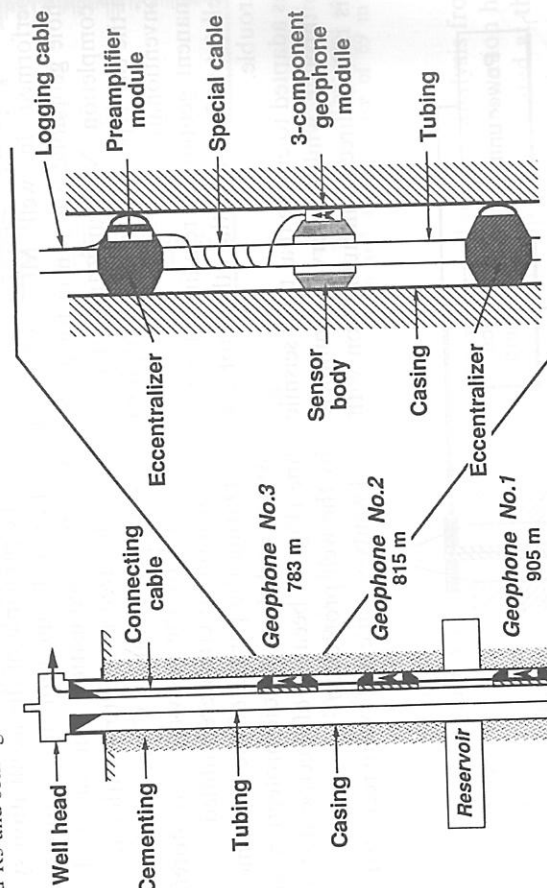
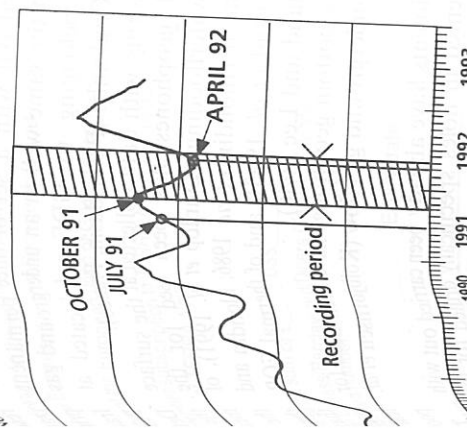


Fig. 4. (a) Location of well MC7 and of the other wells of the Wealden reservoir top. Wells Nos 18, 34 and 37 are located 1.3 to 1.7 km from well MC7.



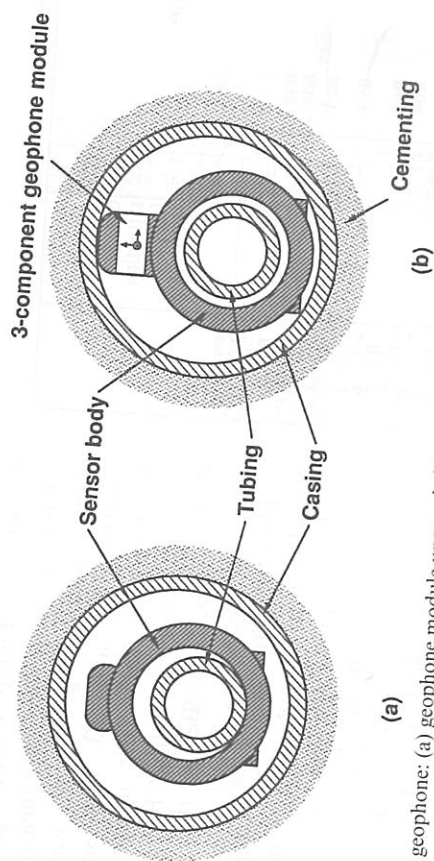


Fig. 5. On-tubing permanent geophone: (a) geophone module uncoupled from the casing during running in; (b) geophone module coupled to the casing.

clamped to the tubing (Fig. 5a). When a sonde is at the required depth a triggering system allows the seismic module to be clamped to the casing wall. At the same time the module is disconnected from the tubing (see Fig. 5b). After that, the seismic module can be considered as a conventional borehole geophone. Its mechanical design and the high clamping force provided by two springs ensure a very good seismic response. Laboratory tests indicated the first tool resonance near 500 Hz in the three components.

The design was adapted to the completion of the well with a 7" casing and a 2 $\frac{7}{8}$ " tubing.

A test was performed in well MC7 where a conventional borehole geophone was run in for a VSP before the tubing completion. No significant difference was found between the two types of downhole geophone (permanent and conventional).

One of the permanent geophones remained for two years inside the well (at 905 m) and the others for one year without any trouble.

The wellhead was adapted to ensure that the 9 seismic signals could pass through while preserving complete safety. Well MC7 is not in direct communication with

the gas reservoir, but the surface completion was designed as if it were. The wellhead included 3 electric connectors, connected to the wireline cables, enabling the connection of the 3 sondes to a recording unit, for either seismic monitoring or microseismic surveying.

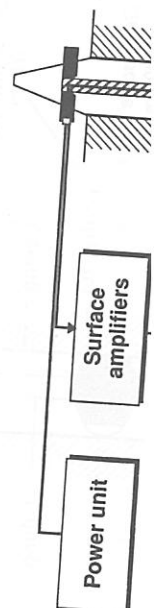
Passive monitoring: the microseismic surveying experiment

The passive surveying experiment started in October 1991 and was stopped at the end of April 1992 as indicated in Fig. 2.

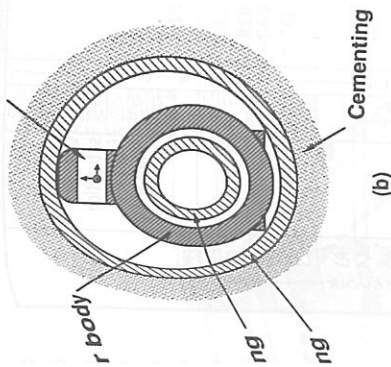
The principle of the acquisition system is represented in Fig. 6. To monitor the microseismic activity a SEIS-SCOPE acquisition unit was used. The nine channels were digitized in real time with a frequency bandpass of 4 kHz per channel. Corresponding digital data were analysed by the software and stored on hard disk if acquisition criteria were fulfilled.

During the period of the experiment, the acquisition system and the cathodic protection were alternately on line (Fig. 7) because of electric disturbances generated by the well protection.

Twenty-seven events were recorded during this survey



3-component geophone module



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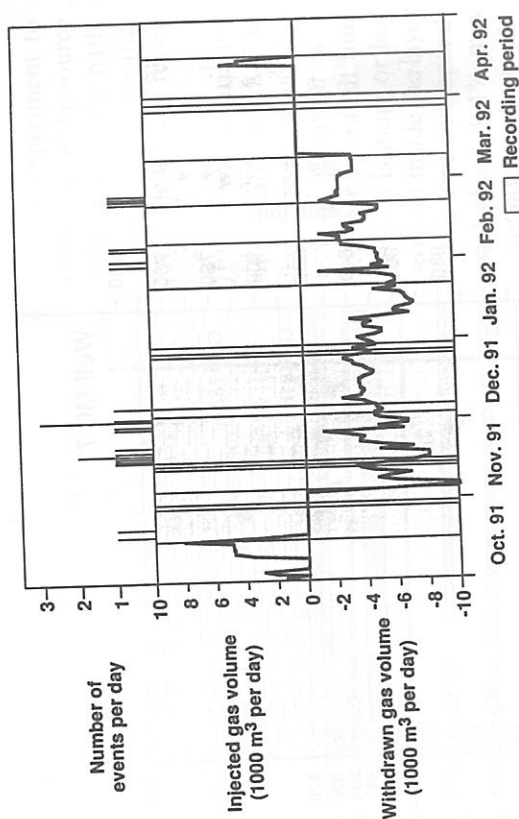
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Fig. 7. Relationship between acoustic activity and variations of gas volumes in relation to injection and withdrawal (over a 7 month period). The survey periods are shown by grey areas. The gas volumes (injected or withdrawn) are given in thousands of standard cubic metres per day. The negative values correspond to gas volumes withdrawn and positive ones to injected volumes. The number of microseismic events recorded per day (one to three) is given in the histogram in the upper part of the figure.



with a maximum of 3 in the same day. These events seem to be associated with great variations in the volumes injected or withdrawn. This can be seen in Fig. 7 where injected and withdrawn gas volumes are plotted for wells 18, 34 and 37 which are located between 1.3 and 1.7 km from well MC7 (Fig. 1). When the withdrawal flow rate was constant (such as during December 1991) or when no injection or withdrawal was in progress (such as in April 1992) no microseismicity was detected. When injection started in April 1992, no microseismic events were recorded, perhaps because microseismicity could be time-delayed in relation to the variations in the gas activity.

Event location was performed by triangulation and by polarization analysis when possible, i.e. if the event signal contained a P/S wave succession (Deflandre and Dubesset 1992). In Fig. 8 a recording of such an event is presented. The 2D location in the (r, z) plane is given for all the events in Fig. 9: r is the distance between the source and the well and z is the depth. In such a representation, no information about the azimuth of events is given. The size of an event is proportional to its magnitude (ranging from -3 up to 1.5) computed from the signal length for the sensor which was reached first. Such an estimation probably gives greater values, about 1 magnitude point more, than when magnitudes are

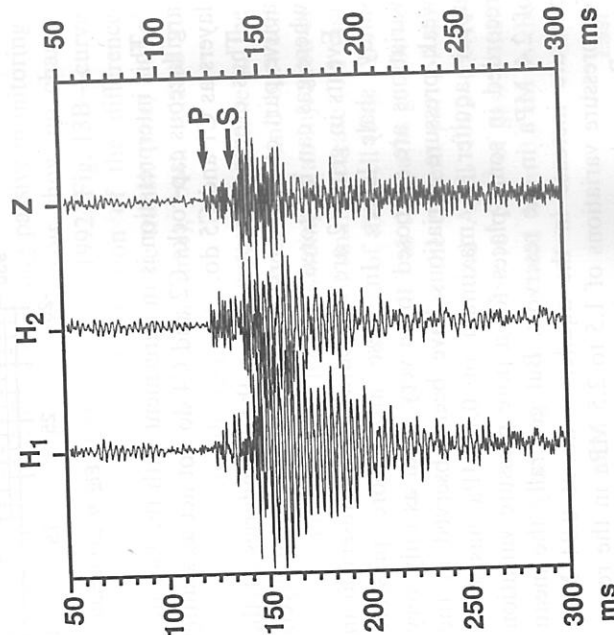


Fig. 8. Example of a microseismic event recorded by geophone No. 3 clamped at 783 m depth. The point source was located at a depth of 836 m and at a distance of 69 m from the well in the N26°W direction.

description based on core analysis from a great number of wells, the following interpretation has been developed. Events of group 1 are located at the top and bottom