Petrophysics
Cement of the Geo-sciences

Inaugural Lecture

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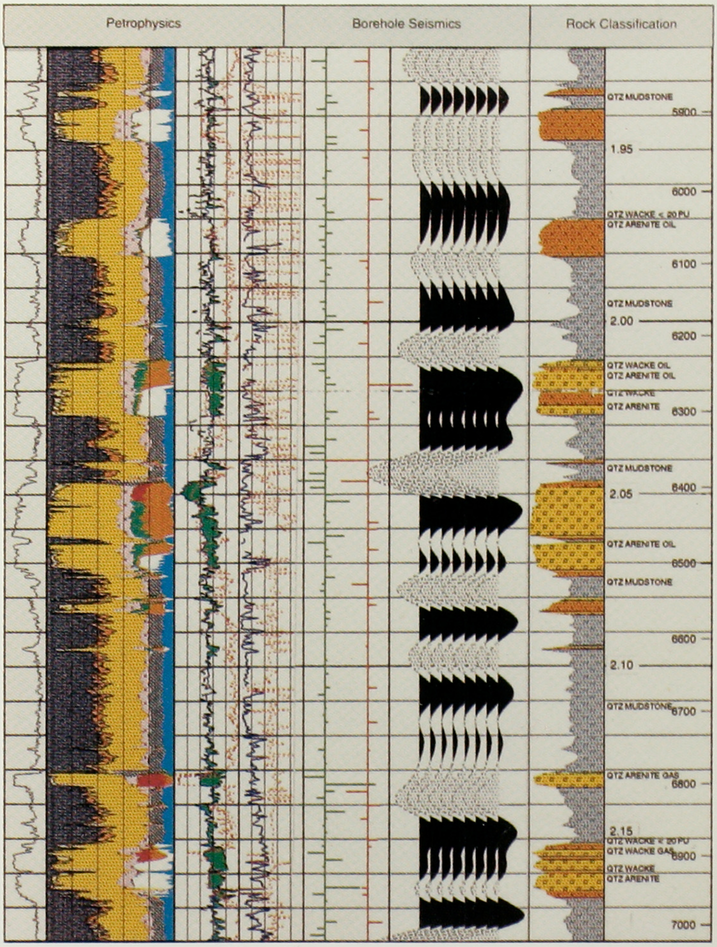

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Petrofysica

Het Cement van de Aard-Wetenschappen

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On the cover a picture from "Single well data integration" courtesy the Oilfield Review July 1992 is shown.

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Het Cement van de Aard-Wetenschappen

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door

Ir. M. Peeters

Deze rede werd uitgeproken in het Nederlands, maar in verband met de Engelstalige bezoekers in het Engels uitgegeven.

Mijnheer de rector magnificus,
leden van het college van bestuur, collegae hoogleraren
dames en heren docenten, studenten en medewerkers van deze
universitaire gemeenschap, en voorts allen die door uw
aanwezigheid van uw belangstelling blijk geeft,

Zeer gewaardeerde toehoorders,

Petrophysics : Cement of the Geo-Sciences

Petrophysics is the physics of subsurface rocks, as indicated by the use of the Greek word Petros which means stone. Petrophysics is the science or some would say the art of determining physical rock properties [1]. The petrophysicist performs this task by analysing rock samples in the laboratory, or by measuring the properties with instruments deep down in boreholes. Petrophysics is not restricted to rocks that contain oil or gas. I had the pleasure to apply petrophysical techniques to the exploration for coal and metal as well. However this chair is in the Petroleum Engineering department, hence I will confine myself in this lecture to oil and gas.

Oil and gas are often encountered several kilometres deep in the earth, and are usually accumulated in the open spaces of reservoir rocks. The term reservoir is very misleading because it evokes erroneous pictures of large caverns filled with oil or gas, while in reality a reservoir consists of a network of tiny pores with diameters which can be as small as a tenth of a mm. Reservoirs are often delineated by sending a strong acoustic pulse generated by a source at the surface into the earth, and recording the 'echoes' with strings of 'microphones' on the surface. This technique, called 'seismic' aims at producing an accurate image of the layers which are present below the surface.

To prove the presence of oil or gas, boreholes are required to connect the pore-network with the surface. Like most geo-sciences, petrophysics has evolved from mining, an activity that is almost as old as mankind itself. Think about ice-age men who lived in horizontal holes called caves. History repeats itself, nowadays oil-companies are trying to make a living from horizontal bore-holes.

I will refrain from describing all intermediate steps in history after all I have only got 45 minutes! Moreover, it was only 50 years ago that the term 'Petrophysics' was first used. Our academic staff will be happy to learn that it was the first Professor of Petroleum Engineering at our faculty, J.H.M. Thomeer, who, over drinks with Archie coined the term 'Petrophysics', thus founding a new geo-science. Archie, who rightfully can be called 'the father of petrophysics', worked for Shell in Houston and discovered in the Forties the law which is by far the most frequently used in petrophysics. Archie's law relates the electrical resistivity of a porous rock to respectively the amount of open space in the rock, the part of the pore-volume occupied by water, and the electrical resistivity of this water. Although trained as an electrical engineer, Archie gave up this profession in the Thirties due to the economic crisis and worked in his father's rock quarry business to make a living. Another ironic twist of history, which led Thomas to remark: [2] 'Would Archie have discovered this law without an intimate knowledge of rocks?' obtained by working as cave man?

The mission of petrophysics can be formulated as follows :
'To determine, from laboratory measurements on rock samples, and from measurements with instruments in boreholes, the storage capacity of the rock called *porosity*; the hydraulic conductivity called *permeability*; the fraction of the pore space filled with hydrocarbons, called *saturation*; and the *acoustic velocity*'.

Porosity, permeability, and saturation are indispensable parameters for the geologist to calculate the volume of reservoir rock; and for the reservoir engineer to determine the amount of oil and gas which can be produced from that reservoir. The geophysicist needs the acoustic velocities to convert the 'echoes' of subsurface layers, which were recorded as a function of travel time, to images that show these layers at the correct sub-surface depth. The links with other Petroleum Engineering and Exploration disciplines, which I just described, will be the *leitmotiv* of this address. When I have come to the end I hope that you will fully agree with the title: 'Petrophysics is the cement of the geo-sciences'.

Petrophysicists strive to determine rock properties. In a borehole a hollow bit can be attached to the drillstring, to cut a cylindrical piece of rock, called a core, in a process which resembles the pitting of an apple with an apple-bore. One of the limitations of measuring properties on core samples is that they only represent a tiny part of the reservoir. The volume of a sample is about 100 cm^3 whereas the reservoir typically has a volume of several billion m^3. A factor 10^{13} difference. Measuring rock properties on one sample and drawing conclusions for the entire reservoir is equivalent to describing an ocean based on the analysis of one bucket of sea water. Moreover only one thing is certain: the rock sample is not the same as it was in the reservoir. It was disturbed during the cutting process, invaded by drilling fluids, and its pressure and temperature reduced when the core was brought to the surface. Still, cores can provide the only physical proof that the rock has porosity and that it can conduct hydrocarbons, so I like to share with you some spectacular advances in core analysis.

In medical sciences Röntgen (X) radiation tomography and Nuclear Magnetic Resonance are used routinely to look into a body without any interference. Both techniques are able to isolate from the total X-ray attenuation or electromagnetic resonance signal, the contributions of very small volume elements. A composite picture of these individual contributions shows the variation in attenuation or resonance throughout the sample. Small fractures, impermeable layers, and even the flow of different fluids can be visualised.

Another advance I like to show is the analysis of Scanning Electron Microscope pictures. This is another example of cross fertilisation: the image analysis techniques originally developed for satellite photos are applied to delineate grains and identify minerals. Image analysis of Scanning Electron Microscopy pictures combined with network theories can now provide estimates of porosity, shale content, and surface to volume ratios. These results are invaluable for a more fundamental approach of capillarity, relative permeability and conductivity behaviour of reservoir rocks.

Contrary to rock-sample analysis, the start of running electronic instruments in boreholes at the end of cables is very accurately known. In 1927, Monsieur Doll working for the Schlumberger brothers lowered three lead electrodes held together with ropes in a hole near Pechelbron in the Elzas. He sent down a current and measured the voltage on the surface. The Schlumberger brothers can not be blamed of false modesty when they called this technique 'electrical coring' [3]. Since then a very diverse range of instruments was developed for measuring for instance, electrical resistivity, acoustic-velocity, neutron-absorption, gamma-ray scattering, gravity nuclear- magnetism, and dielectric-constants The measurements recorded as a function of depth are called 'logs' and the instruments 'tools'.

The diversity of these measurements is what attracted me to petrophysics from the start, and still fascinates me 25 years later. All these measurements are carried out in the restricted space of boreholes, which often have diameters less than 20 cm; pressures of up to 500 bar and temperatures of up to 250 °C. The logging industry is much less glamorous than the space industry, but there is some similarity. First of all you cannot go there yourself, electronics have to stand up to accelerations of several *g's*, and data are transmitted over large distances. The first part of this statement 'you cannot go there yourself', may be challenged by NASA because men went to the moon, and by the dean of our faculty because he went down in an 'oil-mine' in the Fifties [11]. The oil was collected in galleries by placing buckets under dripping layers, similar to collecting latex from rubber trees. This mine was located near Pechelbron in the Elzas. The attentive observer will recognise another twist of history: this was the same place where Schlumberger ran their first resistivity instrument in a bore-hole in 1927.

Many instruments such as particle accelerators, gamma-spectrometers, and gravity meters that are room-size on the earth surface were miniaturised to fit into high-pressure vessels and dewar flasks to protect them from the hostile borehole environment. In this way the instruments do not take up more room than a string of milk-bottles.

Despite all these efforts over the past 70 years, there is still no single instrument available that can directly measure what we really want to know i.e. porosity, permeability, or saturation. We rely on empirical relations between the parameters that we can measure and the properties which we need. This is the major difference with 'pure physics' where a brilliant researcher can come up with a new law with universal validity. Our 'laws' are sometimes only valid for a single sand layer! This lack of universal validity is both a source of frustration and of satisfaction in our profession. The young physicist 'I. Nowit', fresh from university, may take the physics in petrophysics serious and measures e.g. 100 dielectric constants on rock samples from three oil fields. He finds a very good correlation and dreams already from the 'Nowit' Law, but alas in the fourth field the relationship breaks down completely. It also means that petrophysicists, in their quest for empirical solutions, often perceive relations that are obscure to all non-petrophysicists.

This is where science stops and the art in petrophysics begins, as mentioned in the introduction. Is this surprising? No. Rocks are too complex to describe fully by a fixed set of physical parameters. Geologists have of course realised this since they started their profession several centuries ago. When they describe rocks they use colour, texture, even taste, and come up with a name such as: 'Shaly sandstone, brownish yellow, angular grains, well sorted, with traces of glauconite'. I love petrophysics but can not imagine that we will ever invent techniques which come up with a similar description of a piece of rock using instruments several kilometres deep in the earth.

These limitations are also illustrated by what is called 'geochemical logging'. One of the great accomplishments of nuclear logging is that a tiny accelerator was built called 'minitron' with the size of a sherry-glass. Atlas Wireline Services were the first to do this in the Sixties [4]. This minitron produces short bursts of very high-energy neutrons. When these neutrons collide with the nuclei of atoms gamma-rays are produced of which the energy is often a direct indication for the presence of a certain element. This process called spectral analysis enables the determination of elemental concentrations for silicium, calcium, iron, chlorine, hydrogen. This is in itself a very impressive technical achievement, and comes close to the original dream of the Schlumberger brothers 'Electrical coring'.

However, knowing the elements is not the same as knowing the minerals. The latter have no fixed chemical composition and determining the mineralogy accurately will remain elusive, unless the response is calibrated with accurate measurements on core samples. Archie, who, as I mentioned before, discovered the petrophysical law that comes closest to global validity, said when faced with a difficult interpretation problem: 'Have you looked at the rocks?' [2] These words from the Forties underline that without geological constraints petrophysics often looses its significance.

I am back at the interaction between disciplines and like to quote Archie again. He said 'Use all available data to arrive at the solution which best fits the information'. He sowed the seeds for the multi-disciplinary approach in geo-sciences that today is strongly advocated by the captains of our industry. Pink [5], in a recent article said : ...increasingly the explorer, the petroleum engineer, the production engineer, must evaluate [the reservoir] together .... a thorough multi-disciplinary analysis of early and comprehensive data, [will] enable a better evaluation of the uncertainties and inherent risks of major projects. Baird [6] remarked : The technology deployed today is both more complex and multi-disciplinary....... petrophysicists should gain hands-on experience in seismic processing & interpretation'.

As you will remember 'seismic' is the technique that uses reflections of acoustic waves to make a picture of the subsurface. Acoustic methods applied from the surface have a physical limitation in vertical resolution of about 20 m. Only waves with frequencies below some 100 Hz have a low attenuation and can therefore be detected after travelling from the surface to the reservoir and back again. Borehole measurements have a vertical resolution which is usually better than 0.5 m, but only measure a few meters deep. The two meet when acoustic waves generated on the surface are recorded in the borehole, or when acoustic measurements are carried out between boreholes It is therefore not a coincidence that geophysical and petrophysical research in our industry are gradually merging.

Thanks to Van Baaren who led the petrophysical section in this faculty before me, we are in an excellent position to carry out fundamental research in this border area between geophysics and petrophysics. We have in the Dietz laboratory of our faculty a cell available in which acoustic measurements can be carried out under the high pressure and temperature conditions that prevail in the reservoir on rock samples up to 60 cm long and 40 cm wide. This equipment which is unique in the world, is matched by expertise in manufacturing artificial porous rocks, and a good background in the theory of acoustic wave propagation. These are the reasons why renowned institutes like Institute Français du Petrole, and Imperial College cooperate with us in European Community programmes.

Soon we hope to be able to measure acoustic waves in this cell with frequencies down to a few hundred Hertz, in the frequency range used for seismic surveys and measurements between boreholes. The latter technique is still in its infancy but has great potential, because it would allow us to make images of layers with an resolution of some 5 m. These layers are not resolved with surface seismic.

The higher resolution that the combination of petrophysics and geophysics can offer is of paramount importance in mature oil provinces like the North Sea, where the chance of finding additional large accumulations in the 100 to 1000 MMbbls (16 to 160 million m^3) class is very slim. Nevertheless the presence of an extensive infrastructure of platforms and pipelines renders some accumulations between 1-10 MMbbls (160-1,600 thousand m^3) economic, if we can find them. A considerable number of smaller accumulations is usually found in and around large reservoirs, but detecting accumulations with a footprint the size of a soccer field and a height of 30 m is often not possible with conventional seismic, which has a resolution of about 20 m.

The process of calibrating seismic signals with borehole measurements to extrapolate rock properties away from the hole with a resolution of some 5 m is called 'lateral prediction'. I am happy to say that the cooperation between geophysics and petrophysics necessary to make this process a

success is excellent in our faculty. We offer joint projects to students and share data processing techniques.

Cooperation and working in multi-disciplinary teams is not restricted to the petrophysics-geophysics 'axis'. The traditional links with production geology are also maintained. Not in the least because Professor Weber in that group has worked as a petrophysicist for a considerable time and promoted both the spectral gamma-log and mini-permeameter. Together with Professor Ypma we coach a PhD project on induced spectral gamma-logging. The cooperation transcends even group boundaries, and I am pleased to have been 'instrumental' in the acquisition of a scanning electron microscope and image analysis equipment for our faculty.

The role of 'cement' that petrophysics can play was also illustrated during the formation of the Research School (Centre for Technical Geo-science). In this school production geology, geophysics, reservoir engineering, and geological engineering groups from our faculty, will join the Acoustics section of Professor Berkhout in the physics faculty, and the electromagnetic group of Professors De Hoop & Van Den Berg.

I will not dwell very long on the state of technology of petrophysics. For those sincerely interested I refer to the excellent overviews in the May-June 1992 volume of the Journal of our Society of Professional Well Log Analysts SPWLA [7,8,9,10]. In this issue comprehensive reviews are given on acoustic, nuclear, and resistivity logging. On the subject of the SPWLA I am pleased to be able to announce that a new Dutch Chapter of the SPWLA will be formed right after this ceremony in this very Aula.

In the remainder of this talk I will compare the current status of petrophysics with the needs and trends which I foresee. Needless to say that this part is strongly coloured by my own experience, and training. The magic year 2000 being very near, it is of course a lot easier to predict what we expect to see in the next century.

The main challenge in the industrialised countries will be the quest for small accumulations using slim boreholes. To maintain a degree of independence, it will be essential to find and develop economically the small oil fields near the large fields, which will be depleted in the next decades.

This quest will only be successful if the universities, oil companies and contractors work together to provide high-resolution appraisal techniques and slim-line borehole instruments, supported by enhanced core- and log-interpretation models.

Core analysis has developed rapidly over the last decade from measuring rock parameters on plug-size samples to a discipline that uses highly sophisticated scanning techniques that provide detailed images of the rock. The combination of a network theory that describes the pores and the image analysis of scanning electron microscope pictures will give a much more fundamental understanding of flow and capillary behaviour of reservoir rocks. This will in turn lead to improved models which describe e.g. the relation between rock resistivity and oil-saturation. This is especially important for shaly-sands where the pore water conductivity described by Archie's law is supplemented by the clay conductivity. Since Archie, some 30 different shaly-sand saturation equations have been published. I am proud to have worked for Lambert Smits, who derived with Monroe Waxman the Waxman-Smits equation, which is still universally applied today.

Effective-medium models can describe the behaviour of shaly sands based on first principles, and many 'laws' including the 'good old' Archie equation turned out to be just a sub-set of this general approach. These models can be used for 'non-Archie' rocks, which in the case of finely laminated sands can produce a lot of oil but are often overlooked with conventional models.

Closer to home, our acoustics group here in Delft has an ambitious programme to measure acoustic wave propagation on rock samples to quantify the effect of the mineral composition and pore fluids. The ultimate aim is a better inversion of acoustic waves, which would enable the deduction of lithological and pore-fill information from seismic and sonic logs. This information is essential to identify small oil accumulations around large mature fields e.g. in the North Sea, which I mentioned earlier.

Resistivity logging is the oldest type of borehole measurement and is relatively simple. Nevertheless we still lack a tool which can measure the resistivity with a high vertical resolution and at the same time measures beyond the zone around the borehole, which is disturbed by the drilling process. A tool with a large number of identical electrodes was proposed by Shell Research. Software would be used to focus the signals of the electrodes.

This technology for new tools is matched by new software capable of inverting resistivity logs recorded with existing tools. The result of the inversion is a log that is more accurate and has a higher vertical resolution. These data are essential for the continuation in the Nineties of the trend identified by Pink [5] for the Eighties: '80% of the additions to the oil reserves found by Shell came from field studies and appraisal activities'. To put it simply: the most successful way to find new oil is to look in and around old fields.

However it is not sufficient to determine the original oil saturations in old fields. Current saturations are also required to determine where by-passed oil might be located. This often means that information has to be gathered through the steel casing in existing wells. Measuring electric resistivity thru the steel casing with a conductivity that is several orders of magnitude larger than the rock is seriously considered. Preliminary investigations look promising. However, quoting R. Woodhouse : 'the process is similar to subtracting two elephants to find a mouse'.

Nuclear logging offers an alternative method to get information on reservoir rock from behind steel casing. Pulsed neutron tools send high energy neutrons right through the casing and record the gamma-rays produced when these neutrons interact with the rock material and pore fluids. Gamma-rays emitted by carbon atoms and by oxygen atoms can be separated. The ratio of the carbon over oxygen gamma-ray count-rates is a good indicator for the presence of oil, because water contains very little carbon and a lot of oxygen while for oil it is the other way around. The gamma-ray detection efficiency is determined by the size and the density of scintillation-crystals. The detector technology has made large strides forward and the same detection efficiency is now obtained with a 25 mm crystal, that was only possible with a 75 mm crystal a decade ago.

This development is again matched by advances in computing speed. Until the late Eighties, very large tanks filled with different rock types and fluids were required to characterise and calibrate the response of nuclear tools. To calculate this tool response with Monte-Carlo computer programmes, that simulate the behaviour of millions of neutrons, could easily take one month of computer time in 1985. When I started Monte Carlo simulations two years ago it took a couple of days, and recently this was reduced to a couple of hours. I foresee that the construction of experimental logging instruments and calibration facilities that have tied up many millions of dollars in the past, will be significantly reduced.

Designing and determining tool responses will be done by Monte Carlo simulation, and only a few benchmark experiments will be required.. Flexibility in the design will increase accordingly and a tool development cycle that took five years will be reduced to two years or less.

A new method for Multi-phase flow measurements was a spin-off of pulsed neutron logging. Although measuring the amounts of oil, gas, and water in the borehole is strictly speaking not a petrophysical subject it happens to be my 'hobby' in Shell. The idea is to use the gamma-rays produced by carbon and oxygen atoms in the borehole to estimate the oil and water volume fractions. The effect of the borehole fluid is usually an unwanted disturbance, and for nuclear tools it is often much larger than the signal from the reservoir rock. Using a phrase from the bridge-game : 'Going through the strong to the weak hand', we turned a weakness of the nuclear tool for formation evaluation to a strong point for multi-phase flow measurements. With some luck we will have a new tool based on this idea in the oil field in the course of 1994.

The intrinsic safety of pulsed neutron tools which use small electronic 'minitron' accelerators is a prime advantage. Switched off they are harmless. These tools are already replacing neutron instruments which contain chemical neutron sources. The replacement of chemical gamma sources in density tools will probably take another few years. The development of 'betatrons' or 'linear accelerators' is very costly, and has to my knowledge not been tested in the field. Still these developments are mandatory not only to better protect personnel and obviate transport of sources in large paraffin and lead containers, but also to protect producing wells where the loss of a chemical source could lead to permanent closure and loss of many millions of dollars. Stricter governmental rules are expected and should be welcomed as long as they will apply world-wide.

Slimhole logging tools are required for the evaluation of the small diameter holes that are essential for the development of the small accumulations in and around the mature fields. We need these tools to fulfil the promise of slim-hole drilling **and** evaluation . I predict that shortly after the year 2000 we will be able to drill slim-holes that serve as exploration / appraisal / and production wells in one go. Possibly, these wells will be drilled from existing locations on land in heavily populated areas, or from existing platforms in densely navigated waters. These wells will therefore be highly deviated or horizontal.

To further reduce the size of the various instruments to a diameter of around 50 mm will be a real challenge. Although reducing the transducers for electrical and acoustic measurements is difficult, it can most probably be done without major technological breakthroughs. However the devices that take fluid and rock samples have mechanical parts that are more difficult to miniaturise, and it is significant that 'smaller' companies like BPB in the UK play a leading role in the innovation of these tools. I believe that slim pulsed neutron and sonic tools with a 43 mm diameter can replace tools with chemical sources. An additional advantage is that the interpretation would be independent of the water salinity and can be applied through casing!

Data processing and transmission has taken large strides. A decade ago transmitting 10 kilo-byte (10,000 letters per second) was typical. Now, we are approaching 1 Mega-byte. (1 million letters per second equivalent to a book of 400 pages). With fibreglass cables an order of magnitude higher data transmission rate is possible. Fibreglass is routinely used for telephone and TV signals, but is more difficult to incorporate in wireline logging cables, because these have to carry their own total weight. The necessity of increasing data-rates is partly off-set by the trend to incorporate processors, with the power of a PC-486 and the size of a matchbox, in every transducer. This development means that full-energy spectra or time decay signals can be analysed downhole with a resolution of 512 channels. This abundance of data triggered the trend to display the rock and borehole wall properties in colourful displays with imaging tools.

Nuclear magnetic resonance (NMR) has in the last 5 years not only revolutionised core analysis. Application of this technique downhole has the potential of determining for sandstone rocks permeability, pore geometry, wettability, and productivity all in one logging run. NMR tools line up the magnetic spins of hydrogen atoms in a magnetic field and measure how fast the spins disperse after the field is switched of. The dispersion or decay of the resonance signal depends on how easy the hydrogen atoms, present in water molecules, can move. If the water is contained in small pores or bound to shales movement is restricted and the decay will be fast. The decay rate gives information on the pore size. It is expected that more powerful downhole magnets will increase the vertical resolution of the tool.

Measuring while drilling with instruments incorporated in the drillpipes has seen a spectacular development in the last 5 years [7]. It is now possible to measure with confidence the resistivity, density, neutron absorption, and natural gamma-radiation. I foresee two main challenges. The first is to decrease the diameter of the pipe sections in which the sensors are placed. This is necessary to enable MWD in slim holes. The second is to bring the sensors much closer to the drill bit. This will ensure that information on layers which are drilled becomes available within a couple of hours instead of a day or more. This time reduction is essential to realise 'geo-steering', which can be defined as using MWD data to plan the direction of the well, and if necessary pull back and deviate from the original path. Real geo-steering is first detecting the objective and later remaining in the target layer with an accuracy of about 0.5 m This will be possible when a string of acoustic transducers is imbedded in the drill-pipe, and when reflections of these acoustic signals are used to detect layer boundaries.

All these developments and innovations can only be achieved by the cooperation of the academic world, the oil-companies and the service companies. These three groups are really much more dependent on each other than they often think or perhaps wish. Unlike in other areas, there should not be a conflict of interest. Contractor research is aimed at developing logging tools and selling data acquired with these tools. Grijalva [12] said: ' practically no oil company conducts engineering into logging tools ...'. because the oil company's main interest is to stimulate contractors to develop new techniques, which will eventually provide data for finding and producing hydrocarbons in a profitable way. Software for interpreting these data is one of their major assets. The emphasis on commercial viability and profitability means that in contractor and oil company research, projects with short lead-times and high chances of success are selected. This in turn leaves a niche for academic research for projects that have long lead-times and relatively low chances of success. Even if unsuccessful their educational value is assured because as the proverb says: 'we learn most from our mistakes'.

I am fascinated to be right in the 'triangle' between these three groups, and contrary to what was stated when I started this hybrid existence, one does not have to be schizophrenic to do these two jobs together, but it certainly helps!

Representatives of the wireline logging service companies
It gives me great pleasure to greet so many of you here, and I apologise once again that this lecture was mainly in Dutch, I hope that the publication in English is some consolation. Many of you have provided material for my petrophysical lectures which I gratefully acknowledge#. I like to single out one person Bill Prins from Schlumberger, who not only gave special support, but also proved: 'A friend in need is a friend indeed'.

Dames en heren hoogleraren en medewerkers van de afdeling Mijnbouwkunde
Binnen zeer korte tijd kreeg ik de steun van zowel de medewerkers in mijn eigen groep, als de administratie en andere service afdelingen. Dit was een groot genoegen en pleit voor uw openheid toen er weer een Shell man binnen kwam. Ik ben dan ook met veel plezier in deze faculteit van start gegaan. Ik hoop oprecht dat we de 'Mijnbouw familiesfeer' kunnen voortzetten en ondanks meningsverschillen over de toekomst en bezetting van de faculteit altijd samen naar oplossingen blijven streven.

Hooggeleerde van de Vuurst de Vries, beste Jaap,
Dat ik hier sta heb ik aan vele mensen te danken, die ik niet allemaal apart kan noemen, maar voor jou wil ik beslist een uitzondering maken Jij gaf mij vertrouwen in een periode toen dit een schaars artikel was. Ik hoop dit vertrouwen nimmer te beschamen.

Hooggeleerde Berkhout, beste Guus,
Jouw steun, raad, en vriendschap in de afgelopen periode waren zeer belangrijk. Wanneer de aard-wetenschappen binnenkort in een Onderzoeks -school samenwerken zullen wij dat vooral aan jouw stuwende kracht te danken hebben. Ik hoop dat je je beslissing om wegens drukke werkzaamheden geen wintertennis meer te spelen zult herzien.

Hooggeleerde Weber, beste Koen,
Wij kennen elkaar al sinds mijn eerste dagen in Shell toen jij het spectrale gamma-ray logging instrument ontwierp, dat ik later gebouwd heb. Door de jaren heen is het altijd een genoegen geweest om met je te praten, niet alleen om je encyclopedische kennis, maar ook wegens je grote gevoel voor humor.

#Schlumberger , Atlas Wireline Services, Halliburton Logging Services, BPB, Core Laboratories,

Hooggeleerde Veltman, beste Ben

Wie kon bevroeden toen ik eind zestiger jaren bij jou afstudeerde dat ik ooit nog eens waarde collega zou mogen zeggen. Jij hebt mij de liefde voor de electrische signaal verwerking bijgebracht waarop ik de rest van mijn loopbaan steunde.

Hooggeleerde Fokkema, beste Jacob,

Je recente benoeming deed mij zeer veel veel genoegen en verzekert de voortzetting van de samenwerking tussen geofysica en petrofysica die wij al waren begonnen. We werken daarbij in de geest van onze decaan die in zijn entree rede zei: "Seismiek is een uiterst waardevol hulpmiddel .. de tijd is rijp voor verdere integratie.".

Waarde Shell collega's

Iemand zei bij mijn benoeming het is hem eindelijk gelukt om van zijn hobby z'n vak te maken. Dat dit is gelukt heb ik vooral aan het ijveren van Mike Pink en Paul van Ditzhuyzen te danken die ik hierbij daarvoor nogmaals dank zeg. Ik dank ook mijn collega's in Rijswijk voor hun geduld en medewerking. Ze zullen vaak het gevoel hebben dat ik altijd in Delft ben als ze mij nodig hebben. Ik kan ze gerust stellen hier in Delft denken ze precies het omgekeerde.

Dames en heren studenten,

Zo waardig vertegenwoordigd door de bestuursleden van de Mijnbouwkundige vereniging. Als u het volgen van mijn colleges even leuk vindt, als ik het geven ervan, dan voorzie ik weinig problemen. Tot nu toe hebt u mij in groten getale aangehoord en ik kan volgende jaargangen beloven, dat het steeds interessanter zal worden. Ik maak nog steeds gebruik van wat mijn oude Natuurkunde leraar Dr. J. Schweerts, hier aanwezig, mij 30 jaar geleden leerde. De gedachte dat ik u iets kan meegeven waar u later gebruik van zult maken geeft mij het prettige gevoel dat ik als "cement" tussen de generaties mag dienen. Teruggekeerd bij het woord cement waarmee ik was begonnen is de circel gesloten en eindig ik dus met,

Geachte toehoorders,

Ik dank u allen voor uw aanwezigheid en uw aandacht.

Ik heb gezegd.

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