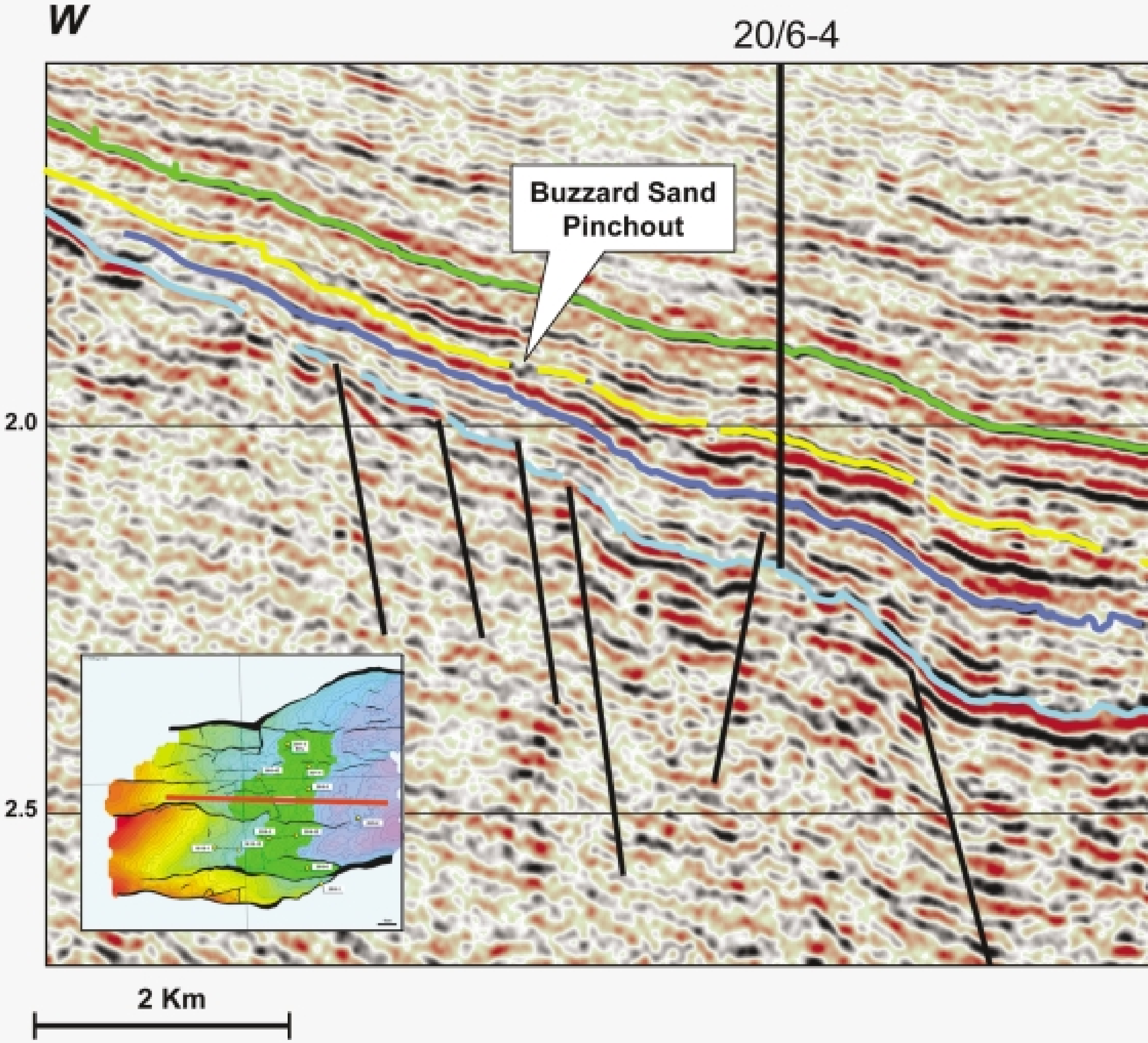
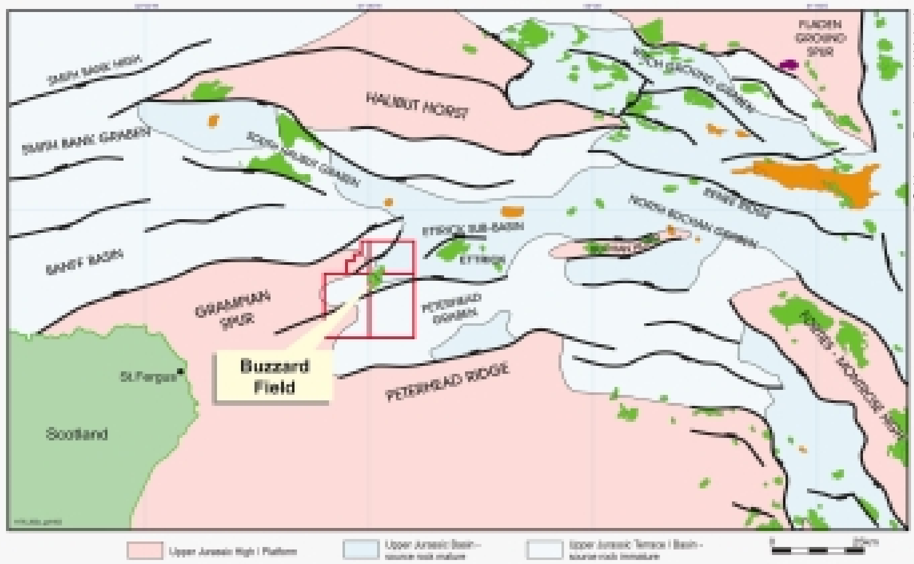
Buzzard

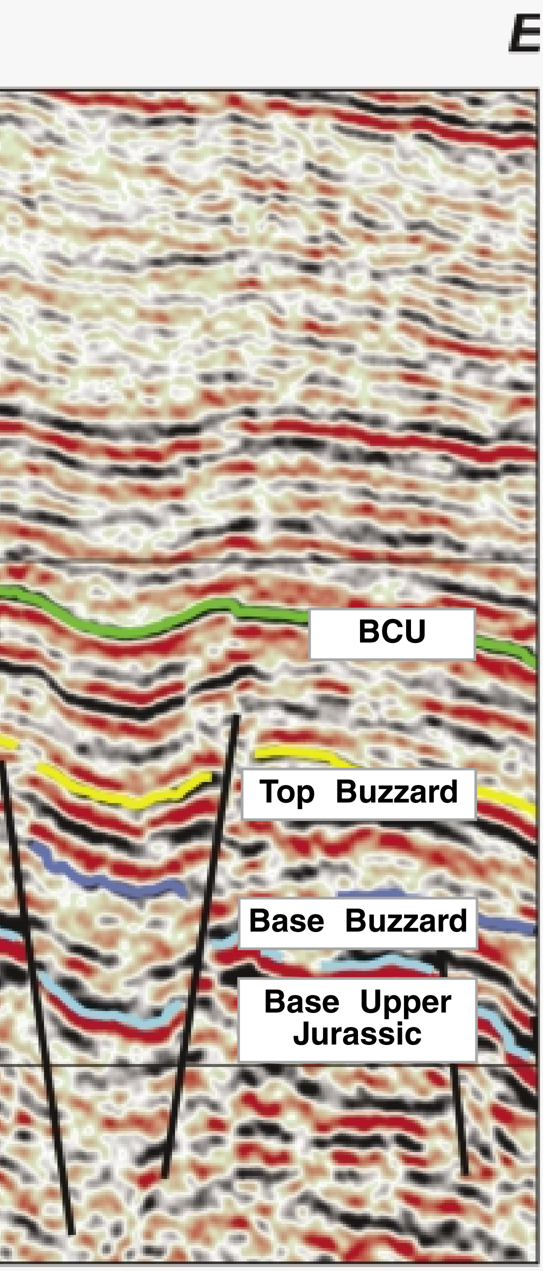
– a discovery based on sound geological thinking

With no apparent closure to the west, the giant Buzzard field was targeted as a stratigraphic trap within Upper Jurassic deep-water sandstones. The discovery should be recognised as a result of high risk/high reward exploration based on a robust geological model and fit for purpose geophysics.



The Buzzard field is located just downdip from the Grampian Spur, an Upper Jurassic platform, and immediately adjacent to Upper Jurassic mature source rock (Kimmeridge Clay Formation) that measures up to 600 m in thickness. Hydrocarbon expulsion was simply updip to the west and directly into the trap. Maturation modelling indicates hydrocarbon generation and migration commenced in the Eocene (some 55 million years ago) and has continued until the present day.





The giant Buzzard oil field is located in the prolific Moray Firth Basin of the North Sea, some 100 kilometres northeast of Aberdeen and in water depth of 100 m. Co-ventures in the project are Nexen Petroleum U.K. Ltd (operator), Petro-Canada Ltd, BG Group and Edinburgh Oil and Gas Plc.

Seismic dip line running from the deep Ettrick Graben (east) towards the Grampian Spur (west) illustrates the Buzzard stratigraphic trap component with Upper Jurassic reservoir sandstones thinning towards west. Well 20/6-4 was the first appraisal well to be drilled following the discovery well 20/6-3 in May 2001. An aggressive appraisal campaign included six appraisal wells and two sidetracks in one year to delineate the extent of the discovery. In addition, two production tests and an injection test were done. A 305 km^2 3D seismic survey was also acquired. A giant oilfield was thus defined with an estimated 1,2 billion barrels (190 million m^3) of oil in place. Current estimates of recoverable reserves exceed 400 million barrels (65 million m^3). *The index map is a depth map on the reservoir level.*

Halfdan Carstens

It must have been quite an exciting moment: We can suspect that the adrenalin was flowing fast. Following years of meticulously developing and soliciting a prospect few explorationists would believe in - and even fewer companies wanted to put their money into - the first well was about to enter the reservoir in the spring of 2001.

"The tension and anticipation was palpable," says Graham Doré, who was at the time chief geologist with the large independent Canadian oil company PanCanadian. "On Friday 11th May the well encountered a significant drilling break. We had oil and gas shows about 200 m through the Upper Jurassic, and there was almost a sense of disbelief in the office as we considered the possibility of having a major discovery on our hands. There followed a few nerve-jangling days as the reservoir was cored and the scale of the find slowly became apparent, but any doubts were finally replaced by elation and excitement when logging confirmed that the reservoir was fully oil bearing. Buzzard had come in big time!"

The discovery well was found to be fully oil-bearing. It was therefore sidetracked 1300 m to the east and successfully established an oil-water contact and proving an oil column of 425 m. The upper part of the reservoir was subsequently tested, flowing a surface-constrained rate of 6547 BOPD of 32° API oil on a 36/64" choke.

Significant potential identified

Four years later we have learned that the Buzzard Field is one of the largest fields to be discovered in the UK continental shelf in the last 25 years. Current reserve estimates are conservatively put in excess of 400 million barrels, but it may well turn out that the field is significantly larger. If that is the case, it will eventually be classified as a *giant* oil field, meaning that the reserves exceed 500 million barrels of oil (80 million m^3).

We may, however, also have learned something about the value of sound geological thinking when exploring mature basins. Geological knowledge may be worth millions of dollars if used correctly and if managers are ready to listen.

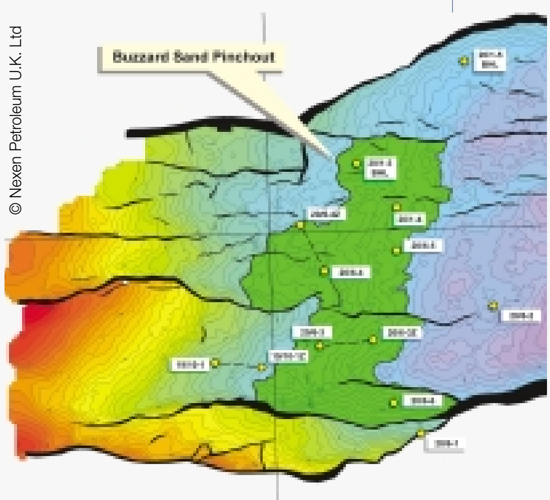
A decade prior to the discovery, the successful prospect existed only in the minds of a few geologists. Their asset was an intimate knowledge, acquired through years of experience, of the geological evolution in this part of the North Sea. Says Doré: "Without good quality seismic data, the prospect was very much based on an idea. But we thought the geological concept looked really good."

Doré first came up with the idea in 1992 when working as a geologist with Amerada Hess. "The prospect was considered too risky. The oil companies were at that time prone to test well defined structural traps rather than subtle stratigraphic tests," he says.

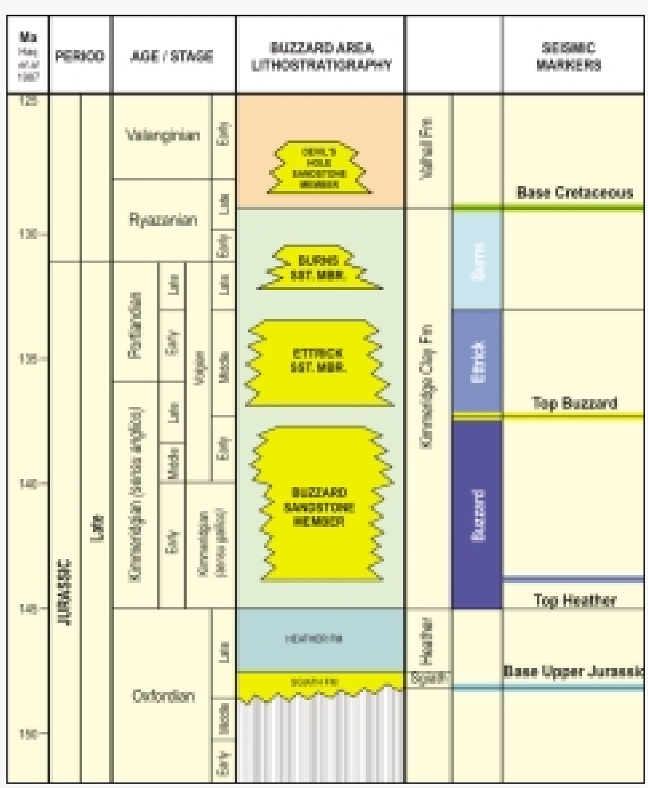
By moving from Amerada to PanCanadian, a new entrant to the North Sea arena, Doré got a new chance to work on his innovative ideas.

"Based on data from well 20/6-2 drilled in 1986, a well that encountered 200 m of submarine gravity flow sands of Upper Jurassic age in the centre of the sub-basin, we knew that fantastic quality reservoir sands existed. A limited number of 2D seismic lines enabled us to sketch a simple map identifying a stratigraphic trap with updip pinchout of the sandstones. The potential size of Buzzard prospect made it a very exciting project to work on."

PanCanadian thus acquired the rights to the licence in 1998. It would take another three years before the prospect had matured and was ready to be tested. "A key fac-



This depth map of the Top Early Volgian (i.e. top reservoir level, compare stratigraphic column below) illustrates the predominance of the east-west oriented faulting separating the field into five separate compartments. Also shown are the updip pinchout and the oil-water contact. The Buzzard Field is considered to be a fault-bounded stratigraphic trap. The field is dip closed to the east. To the north and south the closure is determined by downthrow against the east-west-trending graben-bounding faults. To the west the trap is clearly stratigraphic in nature. This stratigraphic trap is thought to be a simple depositional pinchout at the base of a depositional slope, with the slope to the west acting as an area of sand bypass.



The stratigraphic column shows the Upper Jurassic reservoir sandstones of the southern Moray Firth Basin being encased in Kimmeridge Clay Formation source rocks. The Buzzard reservoir, being older than the Ettrick reservoir further east, has been subdivided into four stratigraphic units. The upper unit, which contains 80 % of the reserves, has a fairly uniform thickness across the field and is characterised by a high net to gross ratio and excellent porosities and permeabilities. Triassic sedimentary rocks or granitic basement generally underlies the Upper Jurassic sequence.

tor in helping to determine the 20/6-3 well location was the successful reprocessing of the original 1995 3D," says John Robbins, senior geophysicist with PanCanadian at the time. "A significant improvement in multiple attenuation and resolution in the Upper Jurassic highlighted key stratigraphic detail and gave us more confidence in the pinchout."

Excellent reservoir properties

The Buzzard Field is situated at the western margin of the Ettrick Sub-basin in the southern part of the Moray Firth Basin (compare page 35). Prior to the discovery of the Buzzard Field, 15 exploratory wells had been drilled within this northeast-southwest trending sub-basin with Jurassic strata plunging below 4000 m. The most significant was the Ettrick Field discovery well (20/2-1) in 1981 that proved the presence of gravity flow sands of Upper Jurassic age.

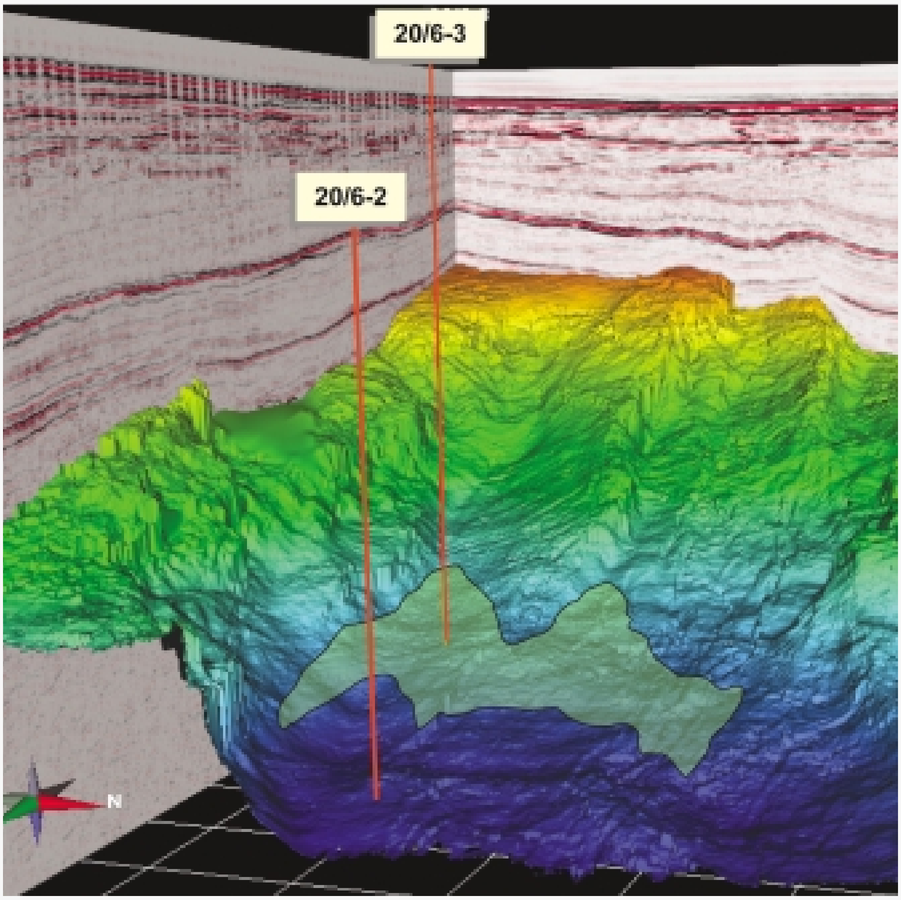
At the end of the Oxfordian in Late Jurassic time (compare stratigraphic column) rift-related tectonics drastically altered the basin geometry, bathymetry and sedimentation style. "Thick organic rich mudstones of the Kimmeridge Clay Formation were subsequently deposited within the Ettrick Sub-basin. Additionally, submarine gravity flows introduced significant amounts of sands from the Halibut Horst to the north and the Grampian Spur to the west," explains Doré.

"We interpreted the sands to have been deposited in a base of slope setting. The sand provenance is thought to be Permian and Triassic age continental clastics eroded from the Grampian Spur hinterland to the west. A river or braided delta system is thought to have fed sediments in an eastwards direction into the Buzzard Graben. These sediments bypass the easterly dipping slope between the shelf and deep water and were deposited at the base of the slope," says Doré.

"The Buzzard Field reservoir units are up to 100 m thick and generally have high net/gross ratios. Porosities vary between 15% and 34% and permeabilities between 200 mD and 18 Darcys," adds Doré, thereby substantiating why he claims this to be an excellent reservoir. "We believe the combination of a high quartz and low clay content is the key to the development of the exceptional reservoir properties. An emplacement of silica cement aids this during the diagenetic history, as the silica added an early rigidity to the reservoir and

Photo: Halfdan Carstens

Graham Doré (right) and senior geophysicist John Robbins can claim that they have been instrumental in the discovery of the Buzzard Field. By combining in depth geological knowledge with appropriate geophysical methods they were able to define an exploration target missed by several others. They recently presented their story in the 1st Biannual Petroleum Geology Conference convened by the Norwegian Petroleum Society in Bergen this year. It has also been published in the *Proceedings of the 6th Petroleum Geology Conference.*



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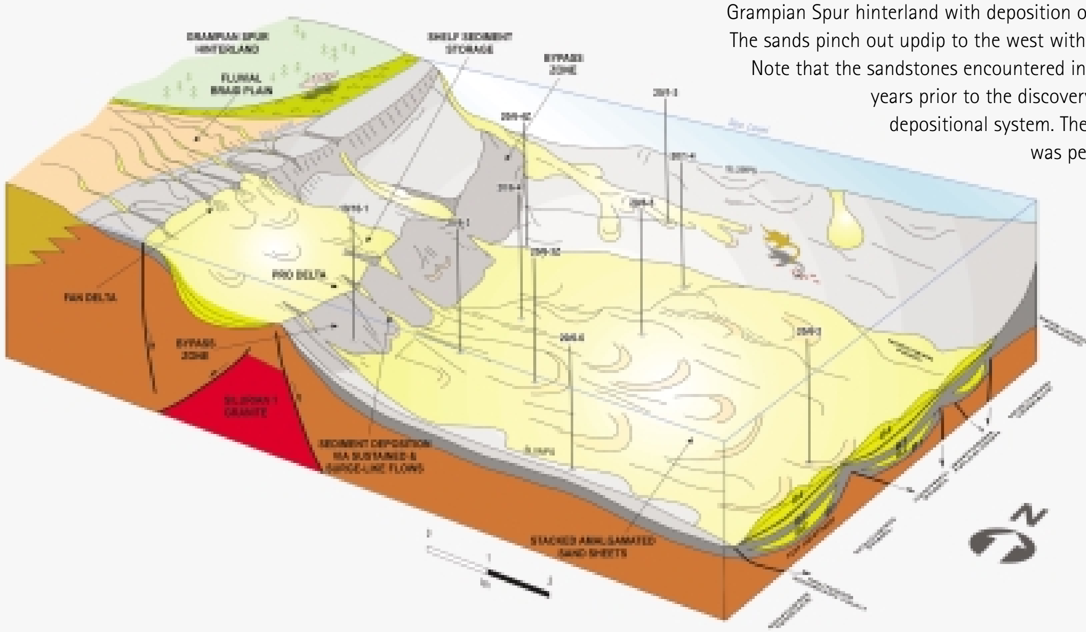
The 3D perspective of the Base Cretaceous seismic reflector - with the field outline superimposed - clearly demonstrates the lack of structural closure in the east-west direction as the structure rises onto the Grampian Spur. Note also the location of the exploration well 20/6-2 drilled in 1986, 15 years before the discovery well 20/6-3, which proved excellent reservoir properties and a 3-4 m hydrocarbon column in a small structural trap.



The Buzzard sandstone depositional model implies a provenance area in the Grampian Spur hinterland with deposition of gravity flow sands in deep water. The sands pinch out updip to the west within the Kimmeridge Clay Formation. Note that the sandstones encountered in exploration well 20/6-2, drilled 15 years prior to the discovery well 20/6-3, are part of the same depositional system. The major risk factor for this prospect was perceived to be the stratigraphic seal to the west.

significantly reduced the compactional effects of the overburden."

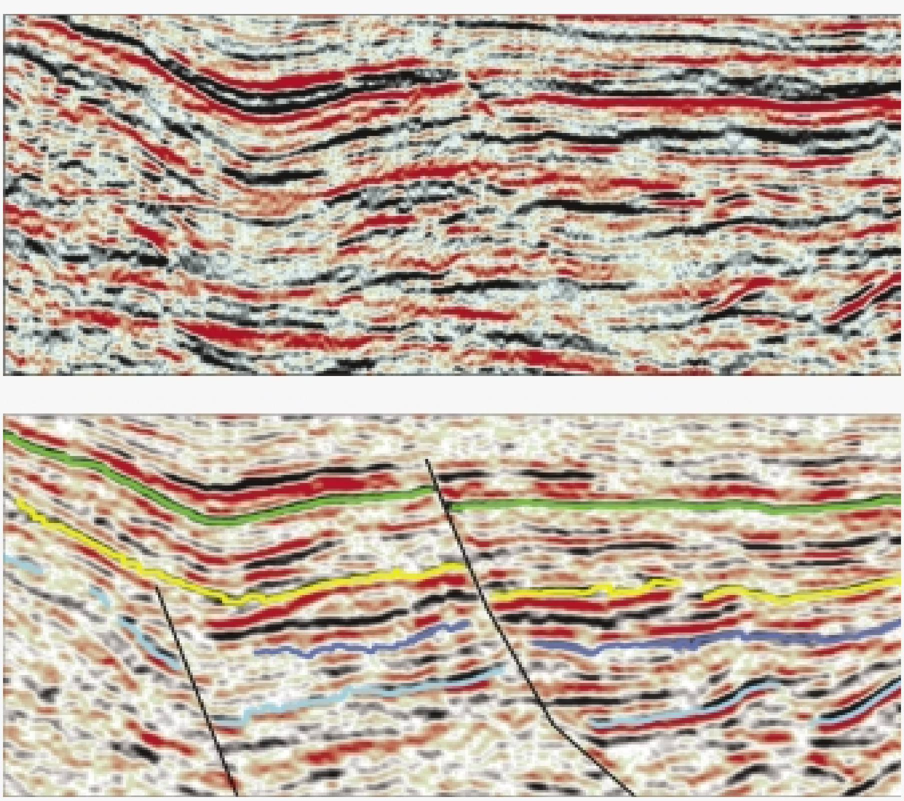
A success story

The Buzzard Field, with more than 1 billion barrels of oil in place discovered at a late stage in the exploration of a mature basin, is nothing less than a success story. "The updip potential was apparently recognized by a significant number of independent oil companies, but the per ceived risks deterred them from drilling the prospect," says Doré.

"The play was originally targeted by well 20/6-2 in 1986. At that time the updip potential was missed or deemed to be too high risk by many oil companies. The Buzzard partnership, however, had a willingness to explore on the basis of a strong geological model and good seismic interpretation, without the requirement of AVO or other seismic attribute indicators. This, combined with a belief in high risk–high reward exploration, led to the drilling of the Buzzard discovery well 20/6-3 in 2001."

Graham Doré and John Robbins claim that a number of geological factors were in favour of the prospect which was given a chance of success of 12% prior to drilling: "The proximity to a significant sand provenance area in combination with a location within an embayment that was focus for sand deposition, played a key role in establishing the depositional model. If the depositional slope was sufficient for sediment bypass - thereby producing an updip pinchout - was a key risk factor. Source and migration were a minor risk factor with oil being generated in a mature basin immediately to the east. Low risk was also envisaged for sealing, also because there was no evidence for late fault reactivation."

Michel T. Halbouty, the celebrated American petroleum geologist, once remarked, "it's about time the good geologist came out of the closet." As evidenced by their discovery of the giant Buzzard Field, Graham Doré and John Robbins have responded punctually to Halbouty's call.



Significant improvements in data quality were achieved when reprocessing the original 3D-data. The yellow colour denotes top reservoir level, while green colour is base cretaceous level.