Trapping

Webster New Collegiate Dictionary: **trap** vb 1b: *to place in a restricted position*



General Considerations

Trapping is the mechanism by which migration of oil and gas is stopped such that an accumulation of these liquids occurs. The identification of traps is one of the most important tasks of the exploration geologist. For a trap to be efficient and commercially viable, a large variety of factors have to be considered. These include:

- The presence of a positive porous permeable structure
- The imperviousness of the seal
- The absence of leaking faults
- The migration of sufficient quantities of HC



General Considerations ctd.

The most important factor in the previous list is the "positive porous permeable structure", which in itself contains several preconditions for a trap. What it really means is that a condition has to exist where a porous, permeable rock is overlain and laterally surrounded by less porous and permeable rocks.

Two types of traps are distinguished where this occurs:

- Structural traps
- Stratigraphics traps



Trap Types

Structural traps are formed by tectonic deformation, while stratigraphic traps are caused by depositional differences between adjacent rock types.

The sketches on the right depict ideal reservoir traps, but they' re not ordered according to the above described subdivision. Try to do this. We will later see where these trap types most commonly occur.



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BASIC PESERVOIR TRAPS IN CROSS SECTION

Trap Types ctd.

By far the most common trap is the anticlinal trap, upper left on the previous slide. The arching (formation of a convex structure) required for it does not need to be caused by tectonic folding, but can also be formed by differential compaction, sedimentary draping over a pre-existing high or uplifted salt domes.

Other important trap types are fault- and unconformity related. Pure stratigraphic traps exist but are rare. They are commonly associated with structural features such as faults or doming, which influence the depositional patterns (syn-sedimentary tectonics), often in a feed-back loop. Such traps are called combination traps and will be discussed later in this lecture.



Structural Traps

The two major mechanisms in forming structural traps are arching through a variety of processes (folding, differential compaction, draping, uplifting of salt or mud domes) and faulting, again in many different ways (extensional, compressional/thrusting, wrench-faulting, rollover faulting). It is very common for arching to be associated with faulting.

The next slide illustrates these structural trap types in more detail. In contrast to the ideal traps illustrated in an earlier slide these are more realistic traps, but still schematically depicted. Some real field examples of structural traps will follow.



Structural Traps ctd.

Notice the common cooccurrence of arching and faulting. The sealing capacity of the faults is very often crucial in determining the trap quality.

BC = Basement complex A = Away from Viewer T = Towards Viewer



Detached normal fault

Salt



Source: North, F.K. (1985) Petroleum Geology, Allen & Unwin

A Research Project on the Sealing Capacity of Faults

At our department we participated in a large-scale research project in the Tucano basin, Brazil, to investigate the sealing capacity of quartzcemented faults. These and their host rock are perfect analogues for actual oilfields situated 200 km to the south. Shown is Ph.D. student Jose Taal at the Falha da Fazenda Brejinha, Bahia State.



A Research Project on the Sealing Capacity of Faults



This cross-cut view shows the main fault and its associated fracture network





Where is the Fault?



What Kind of Fault is This?



Structural Traps: Fault Control



Source: North, F.K. (1985) Petroleum Geology, Allen & Unwin

Faults are in many cases not just associated with structural traps, but they actually generate them, directly or indirectly. Shown are typical examples Petri from regions where they are the dominant trap type.



Contour map of the Forties field, UK North Sea, a giant field that is one of the major producers in this basin. The contour interval is 25m, and the depth in meters subsea. The dashed contour outlines the oil/water contact. Black dots indicate wells. What is the closure of the field?







The Oklahoma City field shows an anticline that is truncated by a mid-Carboniferous unconformity. Notice fault in east and much thicker reservoir units.





The Hassi R' Mel gas field in Algeria is on a horst-like uplift of Precambrian basement. Sourcing is lateral from younger Silurian source rocks. Notice the excellent evaporitic double seal and the dimensions of the field.





Cross-section of the Viking graben in the North Sea between Scotland and Norway. The rifting resulted in antithetic fault and fault blocks that are overlain by drape-folded sedimentary rocks.





Source: North, F.K. (1985) Petroleum Geology, Allen & Unwin

Cross-section through the Mara field, Venezuela. Basement faulting resulted in a horst block with fractured Cretaceous limestone and igneous basement complex, both of which produce oil. Charging is lateral with probably significant losses along the faults.



Source: North, F.K. (1985) Petroleum Geology, Allen & Unwin



Petrol

Source: North, F.K. (1985) Petroleum Geology, Allen & Unwin

This sketch shows schematically the various traps associated with salt domes: Supercap, cap rock, and flanks.

Notice how faulting on the flanks can create traps if the faults are completely sealing.







Map of the Hawkins oil- and gasfield, Texas Gulf Coast. This highly faulted dome is in the supercap of a deepseated salt dome. The radial and longitudinal faults have apparently not affected the trap quality.

vater asphalt 2 km

Source: North, F.K. (1985) Petroleum Geology, Allen & Unwin

Stratigraphic Traps

Source: Levorsen, A.I. (1967) *Geology of Petroleum*, W.H. Freeman and Co



Highly schematic drawings by Levorsen to illustrate the two principal stratigraphic trapping mechanisms, through differential porosities (left) and pinchout (right).



Examples of Stratigraphic Traps 1

These two fields are in the Gulf of Suez, Egypt. The Amal field (top) consists of lenses of Tertiary sandstones. The Belayim field (bottom) shows the same plus faultrelated sandstones to the east of an antithetic fault.

Cross-hatching represents Middle Miocene evaporites.

PLIOCENE-RECENT 1000 Depth (m) 2000 FOCENE-CRETACEO 3000 PALEOZOIC 1000 m

NW

sea level



RUDEIS

FORM



This map shows oil fields in Kansas that follow clear, linear trends. There is even an indication of a shift of the system in the northern part. These fields are aligned along a paleoshoreline and consist of barrier bars.

The analogy with the depositional system on the present East Coast of the USA is shown on the next slide.



Examples of Stratigraphic Traps 3







Unconformities and Combination Traps

On some of the previous slides we have seen that many traps cannot be clearly classified as either structural or stratigraphic. These are the so-called combination traps, and they often involve an unconformity. In fact, unconformities are important not only for the formation of such traps - which are quite common - but also for migration, because they often form a horizon along which permeabilities can be high, while above it they are low.



Unconformity Traps



Source: Levorsen, A.I. (1967) Geology of Petroleum, W.H. Freeman and Co

Sketch of trap types associated with unconformities (above) and their origin through a cycle of trangression and regression (below). Such units are called system tracts in seismic stratigraphic parlance.

Figures are from Levorsen (1975).







Example of an Unconformity Trap

The following slide shows a field which is predominantly an unconformity trap, the Tambaredjo field in Suriname. The field itself is very shallow, and migration has taken place over a distance of several hundred kilometers from a deep-marine source rock offshore, following above an unconformity and finally getting trapped against another one. There might also be an element of stratigraphic trapping in this field.

At our department, we analyze the geometry of the reservoir sandbodies from very high-resolution 3-D seismic, which we calibrate with well log data.



Combination Traps

Source: North, F.K. (1985) Petroleum Geology, Allen & Unwin





- 1,2 true stratigraphic traps
- 3 unconformity traps above the unconformity
- 4 unconformity traps below the unconformity
- 5-7 paleogeomorphic traps (in buried hills)

Paleomorphological features such as buried hills are a common cause of combination traps. Shown here are traps that can be formed in such settings.



Examples of Combination Traps 1



The giant Sunset-Midway field in the San Joaquin Valley (California) shows a combination of pure anticlinal traps, pinchouts, and unconformity traps both in the sub- and the supercrop of the Mio/Pliocene unconformity.

Examples of Combination Traps 2

Source: North, F.K. (1985) Petroleum Geology, Allen & Unwin



In the central Kansas uplift a buried hill led to the formation of fracture porosity in and around it. Drape folding and erosional surfaces with karst form additional reservoirs related to the paleomorphological topography.



Examples of Combination Traps 3



Cross-section of the Ras Gharib field, West coast of Suez graben, Egypt. Oil is found in faults and unconformity traps of the Carboniferous Nubian sandstone. The Miocene reef build-up is related to an uplift and forms a combination trap.



Dynamic Traps

Dynamic traps are the most puzzling of all traps, because they do not have static closure. A pressure difference exists between two or more parts of the field, causing the fluids to move, albeit very slowly. The resulting equipotential lines are not horizontal, but tilted, and so are the oil-water contacts. Oil may get therefore get trapped on the flanks where there is a dynamic closure of an equipotential line.

The following sketches illustrate this.



Hydrostatic vs. Hydrodynamic Trapping



Figure (a) shows the hydrostatic situation. The subsequent figures show situations with either increasing water flows, or increasing density of the oil.



Tilted OWC

Contours of the top of the Tensleep reservoir sandstone in the Sage Creek oilfield (Wyoming). Productive wells are indicated by black circles and dry wells as empty circles.

The OWC is tilted at 150m/km towards the SW. Which way does the water flow?



Study Tasks

- Find out what traps the major Dutch oilfields have. Start with the Groningen field and also look at some of the Cretaceous on- and offshore oil and gas fields.
- The Kashgan oilfield in Kazachstan, discovered in the late 1990s, is one of the largest oilfields worldwide. Find out about its structure, reservoir rock, seal, and trapping mechanism.
- Try to figure out why the fields on the Arabian Platform are so prolific. Does it have to do with the trapping style?

