

## WHY IS THE CERES / TANQUA KAROO SO IMPORTANT FOR THE GEOLOGIST

Our planet is alive and its heart beat can be noticed occasionally. The surface skin (10-60 km thick) consists of floating continents and oceans. Continents occasionally break apart, forming oceans, or weld together, forming mountains and deep troughs. Most of those movements result in volcanic eruptions and earthquakes. This brief introduction will help to understand what we presently see in the Tanqua Karoo and its surroundings.

Between 278 and 230 million years ago four major mountain building periods occurred, resulting in the east-west oriented Swartberg with a trough (Laingsburg Basin) directly north of it. That mountain building also formed the Cederberg and the Hex Rivier/Baviaanskloof Mountains. The Tanqua Basin was formed during that period by the movement of the Cederberg and the Hex Rivier Mountains pushing the surface down and starting a shallow 500-700 meter deep basin. All these movements are the result of pushing and pulling of the southern margin of the supercontinent, called Gondwana. That large super-continent consisted of what are now known as southern Africa, southern South America, Falkland Islands, East Antarctica, and several smaller pieces.

Movements of continents over the surface of the Earth result in variations of the amount of heat from the sun onto the land, which causes ice ages and warm periods with desert climates. Between about 360 and 286 million years ago the southern part of Gondwana became the victim of a long ice age (Dwyka glaciation), covering from East Antarctica, across southern Africa to southern South America. Melting of the ice resulted in thick (800 meters) glacial Dwyka deposits and a sea level rise of about 100-150 meters. That cold time was succeeded by the Ecca period (a duration of about 28 million years) during which the large Karoo Basin formed, stretching from east of Johannesburg to the Karoopoort northeast of Ceres. Much of the Karoo Basin became filled from the northeast with delta deposits in which major coal beds were formed. Any large basin has an irregular floor, resulting in different types of sub-basins and deposits. The location of the still submersed Cederberg and Hex Rivier-Baviaanskloof Mountains formed a stiff block against which the southwestern part of the Karoo Basin moved down for a while. During that time of increasing water depth mainly clays were deposited, followed by the Tanqua Karoo deepwater sand deposits. After that the basin floor moved up, and first clays were deposited followed by the 200 meter thick sand-rich deltas as we see in the Koedoes Mountains. The delta deposits are overlain by river deposits and those by other land deposits. A total of 7-8 km of rock covered the deepwater sands. The weight of that cover is reason that any oil or gas that may have been present in the deep water and delta sediments has been cooked out or pressed upward into overlying sediments that were later removed by erosion.

Although most of the sediment filling the Karoo Basin, came from the northeast, the southwestern part received its sediment from the south-south-west from the forerunners of the Andes, a distance of at least 600-800 km away. During that long transport any coarse sediment was left behind and only fine sand and finer material reached the Tanqua Basin. Major deltas moved from the southwest to the northeast across shallow sea bottoms. Gradually those delta and river deposits moved north-north-east, covering the earlier deposited deepwater sands. Later erosion removed all of that overburden, except what is left on the Koedoes Mountains.

The Tanqua Karoo deepwater sands can be divided into five units (fans), separated by thick shales (schalies). Their total thickness is about 250 meters. To the southeast of Bizansgat is a sixth fan which is separate from the other five fans by a major fault. The five fans differ in thickness (30-60 m), and each one gradually thins the further it flowed into the basin. The middle one (Fan 3) crops out in the cliff along the Ongeluk River. The direction of sediment transport was to the north-north-east. At Vaalfontein it terminates. Fans 1 and 2, numbered from older to younger, only reveal their last part of the fan. The other parts were located south of Ongelukrivier and have been eroded away. Fan 4 came from the west which means that an entire delta, located a few hundred kilometers to the west when the Ceder Mountains and Swartberg were still under water, had shifted to the north. Fan 5 came again from the south. Each fan moved further into the Tanqua Basin than the older ones. The fine-grained sand of a fan was transported from the shallow sea bottom (shelf) via the slope to the flat floor of the basin by turbulent flows (turbidity currents) that were strong enough to keep most of the sand in motion. As soon as a turbidity current reached the basin floor the initial fallout of sand began.

The entire complex of transport and deposition started with a delta that followed the coast line across the shelf when sea level started to fall. Once that lowering stopped sand piled up at the end of a channel. Rapid deposition of that sand made it unstable which resulted in sliding away (slumping). A large piece of the delta broke off and slid down across the slope toward the basin. During that transport the sedimentary slump carved out a canyon across the slope. As soon as that sediment mass reached the basin it slowed down and it started to lose some sediment. Initially a bundle of channel fills resulted (example: Fan 3 at Ongelukrivier) at the mouth of the canyon. It soon changed into a channel with levees (examples: Kleine Rietfontein, along the Gemsbok Rivier, Bloukop). Gradually those channels became shallower and the levees could not constrain most of each turbidity current and the deposition changed to oblong, rather thin sheet sands (examples: Klipfontein, Vaalfontein). The above is a simplified version of the reality.

When sea level started to rise again the coastlines moved back and sand transport across the shelf stopped. Only muds could still be moved to deep water. Those dark colored, very fine-grained sediments commonly are darker than the sands because of the chopped-up plant fragments they contain. Later the sands, when covered with younger material, became sandstones, while the muds became shales. The plant fragments can become coal under the weight of the younger sediments laying on top. Some plant fragments and algae may transfer into oil or natural gas. Normally the quantities are too low to even offset the costs of drilling. Deepwater sands can be fantastic oil reservoirs, sometimes the sands are disconnected and oil has no chance to flow from one layer to the next one, and sometimes there is no oil or gas in them. Most of the organic material that generates oil or gas comes from underlying formations that once were shallow, such as lagoons and bays.

The shales have a possibility to become a source of natural gas. At this time we only know it from the deepwater shales. They are constructed from more than 75% dust-sized quartz. Once buried deep the very fine grains may melt together, making them hard and brittle. Some folding of the rocks will be sufficient to cause fractures. Newly formed gas will move through those little fractures and concentrate in larger fractures, or it moves into the pores of the overlying sandstone. These shales may not be acceptable gas-containing rocks by themselves, but they can add to the reservoir and thus increase the amount of available gas. Do not forget that all the shales in the world make up 60% of all the sediments, which makes it worthwhile to

study them. Oil and gas are non-renewable resources and we do not have sufficient other energy sources to take over.

The big question the reader may have is, why is the Tanqua Karoo so important to the geologist, geophysicist, and the petroleum engineers. There are several types of deepwater fans, one major type is the fine-grained fan. We normally find it in the oceans or in coastal areas at great depth. However, the fine-grained fan is very seldom exposed in outcrop, and when exposed (like the Laingsburg area) it normally becomes intensely folded, and no detailed observations or in-depth layer-by-layer correlations can be made to see if those layers have sand-on-sand contacts that allows oil or gas to move upward. The Tanqua Karoo is the only location in this world where the layers are basically horizontal, making it possible to carry out detailed measurements and to apply those observations and measurements to a buried example that may be a reservoir. One should be aware of the fact that drilling and recovery at sea, in water depths over 1000 m, can easily run into several hundreds of millions of U.S. dollars, and often only one in four wells will be economic. We should improve that number and thus prevent the energy prices to increase steeply. The studies done so far have provided unique information. The second step is to drill a number of holes, retrieve a core, and deploy a string of well logging tools. That project will deal with fresh rock, not weathered, and provides a better three-dimensional distribution of information when added to the outcrop studies. Students from Stellenbosch University will be involved.

Conducting such a program provides work for the local community and business for the area. It will promote visits from others to the area to study those rocks. The program can be used to make offshore drilling on the west coast of South Africa, as well as international, more attractive. It will help a new program from Stellenbosch University, Cape Town University, and the University of the Western Cape, to provide information so students can be hired by the oil- and gas industry operating in South Africa as well as anywhere else. At the moment students have to go to Europe or America to study this direction of geology. Our program can be very helpful for South Africa and the African Countries, as well as the entire world, to insure that oil and natural gas will be longer available than is presently predicted.

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