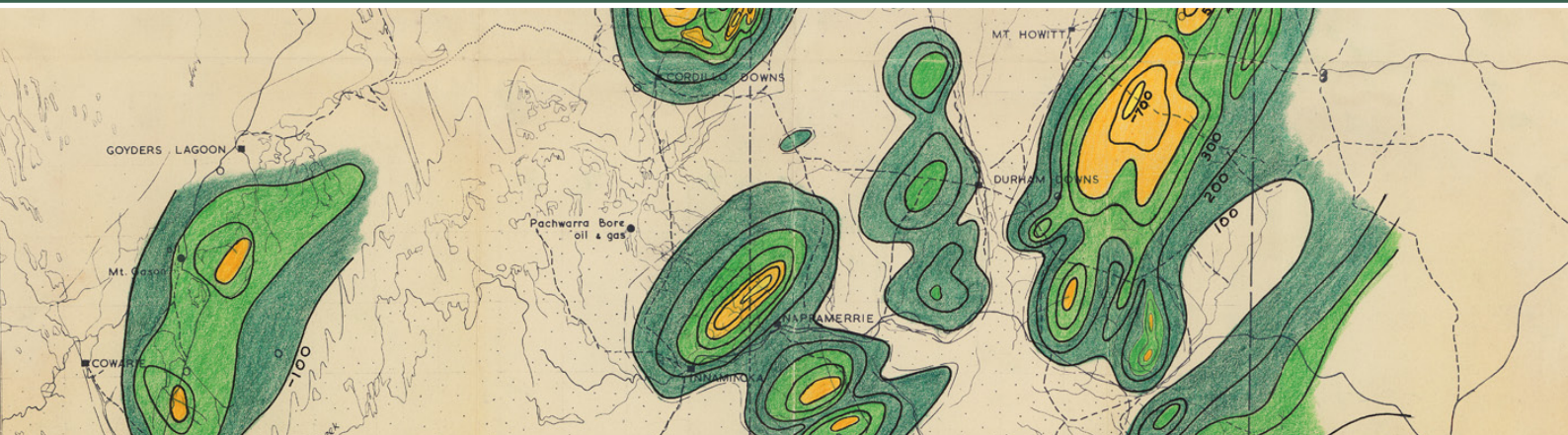


Aerial mapping of Santos's licence areas in South Australia and Queensland, 1957



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Excerpt from 'Where in darnation is Cordillo? A field dog's' tale of the gas discovery at Gidgealpa and of the Cooper Basin oil and gas province', in preparation by Heli Wopfner.

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Cover

Structure contour map produced from aerial survey data recorded by geologists Rudi Brunnschweiler and Heli Wopfner in 136 flying hours. Titled 'Preliminary sketch plan of areas held by Santos Ltd in N.E. South Australia & S.W. Queensland showing principal Mesozoic structures' and dated 15/8/57.

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A new baby and a new idea

In 1957 I was working for Reg Sprigg's consulting firm, Geosurveys of Australia Ltd. Late in March Sprigg sent me to Cordillo Downs to carry out a ground and air reconnaissance of the northeast corner of South Australia and the adjacent area in Queensland for Santos Ltd (Fig. 1). The area was part of Santos's oil exploration tenements, spanning 860 000 km² of northeastern South Australia and southwestern Queensland (Fig. 1). Recognising that the siliceous duricrust (silcrete of the Cordillo Surface) was deformed in sympathy with the underlying Tertiary 'Eyrian' (now Eyre Formation) and the Late Cretaceous Winton Formation, I was able to identify a number of large anticlines with limb dips of up to 22° (Wopfner 1990). In May 1957 I commenced a geological mapping program of the Cordillo area, being assisted by Dick Chase, Stan Row and Greg Swindon.



Figure 1 Locality map showing the extent of the first aerial reconnaissance of the Great Australian Artesian Basin.

In the second week of June it was time for me to return to Adelaide. My wife, Inge, was due to give birth to our second child; the estimated time of delivery being the third week of June. Greg drove me to Betoota to catch the Channel Air Service flight to Leigh Creek. Stan was going to Cordillo to organise some repairs on his Land Rover. Greg and I arrived at Betoota on 13 June 1957 at 9 am, only to learn that the plane was not due for another day. Somehow we got our dates mixed up; or was it just eagerness on my behalf?

Our short wave receiver had been out of action for the last few days, so for want of anything better to do we thought we might try and repair it. We took it out of its housing and found a few wires where the solder had become loose. We had solder and a soldering iron amongst our tools, but the iron measured about 2.5 cm in diameter and was certainly not suitable for soldering fine wires of a wireless circuit. Tom Lloyd, the publican, could not help us either, so what to do? We needed a small piece of copper. Copper? Of course, a penny! We soon found one and proceeded to make a soldering iron out of it. With the hacksaw we cut a triangular piece out of it, drilled a hole at the other end, put a piece of red hot fencing wire through it and beat it for a solid connection. We then smoothed the business end with a fine file, coated it with solder and, voila, there is your soldering iron. This is very well if you have a reasonably equipped workshop, but out in the bush with only the most essential tools, a campfire and a large gibber as anvil it is a different matter altogether. It took us all day, but in the evening we finally had it finished. Greg would attempt to repair the wireless after I departed in the morning; now it was time for a drink.

Next morning I said goodbye to Greg and boarded the Channel Air Service DC-3 aircraft for Adelaide. After stops at Birdsville and Marree, and a plane change at Leigh Creek I arrived at West Beach Airport just on dusk. On my way to the luggage collection I was paged on the intercom to call at the TAA service desk. When I got there the girl handed me a telegram. It read: 'Your wife has given birth to a baby girl. Mother and baby are well. They are in McBride Maternity Hospital. Congratulations and best wishes. Greg'. After Greg had repaired our wireless he received a telegram sent by my wife from the hospital four days ago. I was stunned, grabbed my luggage, hailed a taxi and drove straight to the hospital. It was past 7 pm and well past visiting time when I turned up in the hospital dressed in my khaki bush outfit, tanned a deep shade of bronze and a mob of hair which was long overdue for a cut. When the young nurse ushered me into my wife's room all she could say was, 'Your husband to see you. Whoa! What a hunk of a man'. I wasn't quite sure if it was admiration or astonishment, but at that moment I didn't care. I hugged and caressed my wife and was just grateful that everything had gone well. I was even allowed to have a quick glimpse of my sleeping daughter through the glass pane of the nursery before being ushered out.

After stopping by our home in Klemzig I called at our good friends and neighbours Judith and Peter Stewart who had been taking care of our son Klaus and our dog since Inge had gone to hospital. Judith had given Klaus his dinner and he was already asleep, so Judith suggested letting him sleep and collecting him next day after I had been to see Inge in hospital again. I thanked Judith and Peter and went across to our place. Alone in the empty house I dropped into a swirling hole. In those days it took longer to get from Betoota to Adelaide than to fly from Adelaide to Singapore today. I was dog-tired physically, but at the same time excited and elated by the happy event mixed with feelings of disappointment and remorse because, as at the birth of our first child Klaus, I had not been able to be on Inge's side to lend support when she most needed it. To end that mental turmoil I took refuge in a couple of stiff whiskies and these put me off to sleep.

Before I went to the hospital next morning to see Inge, I phoned Reg Sprigg to let him know that I was in town and to give him a short verbal report. He gave me a few days off so I could take care of our son and prepare for Inge's and the baby's return to home. Then I took the bus into town to see Inge and to have a closer look at my daughter. She was an absolutely delightful creature with fine, black hair on her little head and a continuously moving mouth.

Our son Klaus had a whopper of a cold which did not prevent him playing in the garden with Jane, the little daughter of our neighbours next door, and our dog. There was still a lot of untilled ground, so they could play around to their hearts delight. I tried to make the most of family life, being amazed by the development of our little baby and watch how our son adjusted to the new situation. Actually, he was

quite thrilled to have a little sister, but it was hard to make him understand why he could not see his sister and play with her.

Despite the frequent bush trips, I had been able to establish quite a good looking lawn in front of the house and the backyard started to show the fruits of our joint efforts. Thanks to Inge's loving care our vegetable garden was doing very well indeed. But I could not forget Inge toiling in the garden, trying to dig up that hard Bay of Biscay soil to transform it into something resembling garden soil. The hard work had nearly caused her to lose her baby in March, but the quick and competent actions of our doctor friend Michael Quin-Young, from across the street, prevented the worst. I was wondering if that might have been the reason that our baby daughter arrived a week premature.

Although Reg was very generous as far as my time at the office was concerned, there were some urgent matters that I had to attend to. The Quarterly Progress Report to the Department of Mines was overdue (as usual). I had to compile some geological cross-sections of the northwest corner and prepare statements on progress and results of our mapping, and new insights into type and size of structures encountered in the field. Logistical problems, especially the bad shape of our Land Rovers, had to be discussed and priorities had to be set for the immediate exploration tasks. Ross Grasso, in charge of map compilation, was involved as he produced the photo maps of the Cordillo 4-mile sheet onto which we would ultimately transpose our field data. Thus I had to spend a fair amount of time at our Woodville office.

One day Bruce Wilson, a senior geologist at Geosurveys who had previously worked with Reg at the Mines Department, came across to my office. He had been compiling stratigraphic sections of water bores in the Great Artesian Basin and in the course of his compilation work he had looked at some of the Cordillo air photographs. He laid about half-a-dozen of these photographs on my desk. 'Heli, I think you overlooked some basement outcrops on your Cordillo trip', he said. I looked at the photographs and immediately recognised the low crests near Haddon Creek. 'That's not basement. These are inclined Tertiary and Cretaceous strata', I replied. 'Impossible. Nowhere has the Tertiary been folded to such steep angles', was Bruce's answer. 'Well, I have seen these strata in outcrop and they are certainly neither basement nor Adelaide System', I persisted. We left it at that but naturally the debate reached head office.

On 21 June, three days before her birthday, Inge was released from hospital and I brought her and our new baby daughter to our home at Klemzig. The following day was Saturday and we all enjoyed the togetherness of our enlarged family. In the afternoon Rudi Brunnschweiler, chief stratigrapher at Geosurveys, phoned and told me that Bruce had shown him the photographs with the structures. Rudi was quite agitated and suggested that these sharp ridges might be Devonian sandstones, like those of the Mootwingee Ranges in New South Wales, forming a structural high penetrating the sedimentary cover of the Cretaceous deposits. I repeated what I had told Bruce and insisted that these were Tertiary structures which I had observed in the field already on my reconnaissance in March–April (Fig. 2). We agreed to meet at Woodville on Monday and discuss the matter further.

The meeting at Woodville did not resolve the matter. The fact was that these were moderately dipping sandstone and conglomerate beds resting on a shale–silt formation. I knew their lithology was quite different from that of the sandstones in the Mootwingee Ranges. It was therefore unlikely that the two were of the same age. However, I had no fossil proof that the inclined strata near Haddon were indeed of Cretaceous and Tertiary age. The whole discussion was quite symptomatic of the geological thinking of those days; the thought that strongly deformed strata existed in the Great Artesian Basin was almost unacceptable to most Australian geologists. To resolve the question it was decided that Rudi and I should fly to Cordillo Downs in the company's Sokol aircraft and inspect the structures in the field.

Our departure was scheduled for 2 July, but maintenance work on the plane was not finished until late afternoon, thus we undertook only a short test flight and postponed our departure for the following day. We took off from Parafield Airport at 10 am and touched down at Leigh Creek exactly 3 hours later. After lunch and refuelling we preceded to Marree, followed the Birdsville Track north to Goyder Lagoon, then across the Sturt Stony Desert to Cordillo, where we landed just on 1800 hours. We had informed Greg Swindon that we were coming by telegram, so after we had buzzed the homestead he

came down to the airstrip to pick us up. Rudi was introduced to Roger Beckwith and the other members of the station and, last but not least, to that fabulous Cordillo beef steak.



Figure 2 Pronounced east-dipping sandstones and siltstones of Winton and Eyre formations, capped by silcrete of the Cordillo Surface, forming the east limb of the Nappamilkie Anticline near Haddon Downs Outstation ruins. (Photo 047567)

The prime target of next day's reconnaissance flight was of course the outcrop of inclined strata near Haddon Downs. We took several low passes across the exposures to show Rudi the outcrop pattern typical of the Tertiary silcrete, and then we flew up to view the silcrete-capped escarpment to demonstrate that these were exactly the same rocks as those of the deformed beds. After that we followed the structure north towards Haddon Corner, again flying some low-level passes along the structure (Fig. 3).

At Haddon Corner we turned west. Following the South Australia – Queensland border we flew across the Nappamilkie Anticline and a couple of smaller structures as far as Birdsville, then south again to Smuts Waterhole and along the southern flank of the Cordillo Dome back to Cordillo Station. At the end of that loop I had Rudi convinced, not only that the inclined strata near Haddon were indeed formed by sedimentary rocks of Cretaceous and Tertiary age but also of the existence of the other structures. To settle the argument once and for all we drove to the structures next day to give Rudi the satisfaction of hitting his hammer against the rocks. Now that he was convinced that the deformed strata demonstrated a period of rock deformation in mid Tertiary times, he was gushing with enthusiasm. In typical Rudi fashion he wanted to see more of the region, devoting the next 2 days to reconnaissance flights into Queensland as far as the Cooper and the Durham Downs structure. In addition, he gave Greg Swindon a ride over our mapping area and Betoota. It was a very rewarding time and a most satisfying experience for me personally. On top of it all it was great fun.

On the evening before Rudi was to fly back to Adelaide he asked me what I thought of an aerial inspection of the entire Santos licence areas, both in South Australia and in Queensland, to obtain an overview of the structural pattern. I thought it was a great idea and was absolutely enthusiastic about the possibility to get to know the whole of the Santos licence area. This way local observation would become much more meaningful and could be placed in the greater context of the whole geological province. By now we had definite proof that the duricrusted escarpments and table hills were the expression of tectonic deformations in mid Tertiary time. Thus the silcrete-covered Tertiary could be used as a phantom horizon, reflecting the actual fold structures. That is exactly what I had been doing

during my reconnaissance flights in March and April. However, we could do one better than just making a qualitative assessment of the structures. We could fly past the escarpments and mesas at wing tip level and read the altimeter. Then we could make a low-level pass across the synclinal area, read the altimeter again and would thus obtain the data for the construction of a structure contour map. There would be an unknown factor in the synclines as we had no way to ascertain the thickness of the sediments deposited after deformation. However, by obtaining elevation readings at points where the silcrete surface disappeared below the cover of younger sediments, we could quantify the relative amplitude of the anticline. Thus we could produce a reasonable map on structural trends and fold amplitudes of the licence area in a comparatively short time. Rudi was enthusiastic about that plan too and we discussed the prospects until the small hours of the morning.



Figure 3 Looking south along the eastern limb of the Nappamilkie Anticline, which is dipping 12 to 20°E towards Haddon Syncline. The outcrop shown in Figure 2 is located at the first creek in the foreground. (Photo 409083)

After a rather short night the two of us went out kangaroo shooting. Rudi shot two big, red bucks which I skinned for him. These were perfect hides for him to take home to be tanned.

On 8 July Rudi flew back to Adelaide. I flew with him as far as Tibooburra (New South Wales) where I met up with Stan Row, Dick Chase and Bob Bevies. Bob, the drilling supervisor of Geosurveys, was on his way to Cordillo Downs with an International truck to deliver the first pieces of equipment to set up camp for the forthcoming structural and stratigraphic drilling near Haddon Downs. The four of us proceeded by road to Cordillo. Bob carried a 12-gauge, automatic shotgun, so we took time off to shoot half a dozen ducks at the Cooper crossing to replenish our food supplies.

Three days later when we arrived at Cordillo Downs; Rudi Brunnschweiler and Reg Sprigg were already there waiting for us. They had been inspecting the drilling operation of the Santos well Oodnadatta 1, then flew across to Cordillo to give Reg the opportunity to see the structures near

Haddon Downs for himself. It was the first time that Reg actually set foot on Cordillo ground and he was quite impressed by the clear indications of tectonic deformation. The two flew back to Adelaide the following day. It was on that trip that Reg 'discovered' the Innamincka Dome, the axis of which I had already shown on the map of the March–April reconnaissance (Wopfner 1990). Reg's story (Sprigg 1993) is somewhat different to the one I am telling here.

Mapping anticlines from the air

Back in Adelaide, Rudi quickly convinced John Bonython, Santos chairman, of the advantages of this project and obtained the approval of the Santos Board. Rudi sent me a telegram informing me that he planned to commence the aerial survey in the second half of July.

The Sokol, meaning 'Falcon' in Slavic language, was a single engine, low-wing monoplane with a wing span of 10 m. It was built in Czechoslovakia after World War II under the official type-designation Mráz M1C. It was more or less an enlarged version of the German war time Buecker 181 fitted with a retractable undercarriage adapted from the German executive aircraft Messerschmitt 108. The Buecker 181 seated two people and was used extensively by the German Air Force for pilot training; I myself obtained basic flight training in one of them. During Nazi occupation the Buecker 181 was built in Czechoslovakia and many of the engine fittings of the Sokol still bore the emblem of the German ordnance. The plane was a wooden lattice construction, covered with plywood and fabric, the whole thing being held together by special, two-component glue on a casein base. The aircraft had a fixed, wooden propeller which was powered by a 125 horse power, 4-cylinder in-line, air-cooled engine, giving it a travelling speed of about 165 to 180 km/h. The retractable undercarriage was operated by a hand wheel, situated between the two front seats. It required 15 turns of the wheel to either lower or retract the undercarriage. The flaps were operated by a simple lever situated between pilot's and co-pilot's seats. For his flight from Europe to Australia, Rudi had the rear seat in the plane replaced by an 80 L petrol tank, giving the aircraft an endurance of 5 hours plus. Maximal operational range was about 1600 km. Instrumentation was absolutely basic and there was no wireless. It was a good looking, slightly gull-winged aircraft and it was a joy to fly (Fig. 4).



Figure 4 Sokol flying past Needle Hill, north of Cordillo Downs. The 'needle' is formed by silcrete of the Cordillo Surface. The kangaroo in the foreground is getting ready to take flight. (Photo 409084)

Rudi finally arrived in the Sokol at Cordillo Downs in the afternoon of 22 July; some minor repairs on the plane had prevented an earlier departure. Before commencing with our survey we had to settle a few organisational problems. We knew that aviation fuel was available at all pastoral stations which

were on the circuit of the Channel Air Service, so we could purchase fuel at these places. One major problem was caused by the Department of Civil Aviation. Not having a wireless on board, we had to inform air control of our take-off time, of the limits of our intended survey area and of our flight elevation. This information was sent by telegram via the Flying Doctor network in the morning. However, when we returned sometimes in the afternoon, the regular Flying Doctor network had shut down and it would have been an imposition to activate the alarm button on the Flying Doctor base every time we wanted to send a message saying: 'Have landed safely at xy time'. Only after several telegrams and a couple of failures to 'report back' did the department accept our view that, should we go down somewhere, our chance of survival would not be reduced significantly if our disappearance became known in the morning instead of on the evening before. Needless to say, we had to agree that this was highly irregular and was explicitly at our own risk. Anyhow, in case of an emergency we carried half a dozen tins of corned beef, a box of Sao biscuits and 16 L of water.

On 26 July the Adelaide *Advertiser* newspaper reported, amongst other news on Santos activities at Wilkatana and at Oodnadatta, that: 'The company's aerial unit has commenced systematic geological reconnaissance of the whole of its areas east of Lake Eyre into Queensland'.

As outlined above, we flew wing-tip level to the silcrete covered mesas or escarpments at or near the crest of an anticline and noted the elevation on the altimeter of the aircraft (Fig. 5). Then we descended into the syncline and, flying as low as possible above the ground, we read the altimeter again. Repeating the procedure several times on each individual anticline and plotting the data on an aeronautical map we were able to obtain a fairly accurate picture of the amplitude and extent of the structures. One of us would fly the aircraft whilst the other did the navigation and plotted the observations onto a 16 miles to 1 inch (roughly 1: 1 million) aeronautical map. Every 30 minutes we would switch duties, thus assuring that both of us maintained a high degree of concentration. Depending on the nature of the terrain we would fly between 3.5 and 5 hours a day.

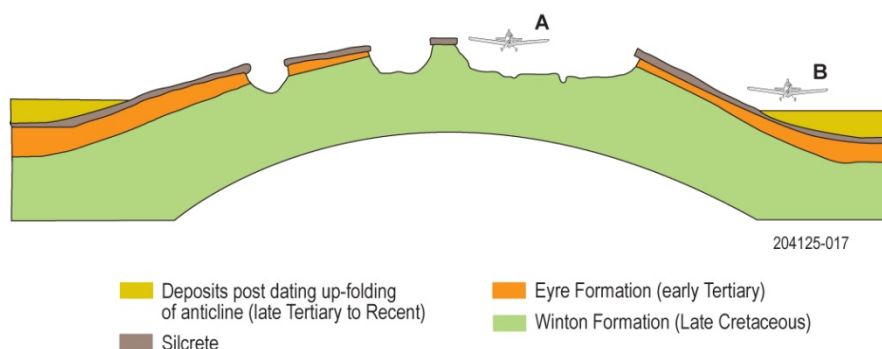


Figure 5 Schematic cross-section of a breached anticline in the Great Artesian Basin, showing positions of aircraft during data gathering: A – wingtip level with mesa at apex of anticline; B – low level pass over ground surface in synclinal area.

The two of us were an ideal team. We were both geologists with an Alpine background and we were accustomed to recognise and identify things from the air. Although I did not hold a valid pilots licence anymore I could still handle a plane competently and I had ample experience in visual navigation and low-level flying. And, most important of all, we were both on the same wavelength.

We divided the total licence area into various segments which we could cover from a central point within each segment. The first was the south-central portion of the Great Artesian Basin, roughly circumscribed by the latitude of Marree, the eastern edge of Lake Eyre, the latitude of Goyder Lagoon and the western margin of the Strzelecki Desert. Unfortunately none of the stations in that area were served by the Channel Air Service, but when we inquired about the availability of aviation gasoline we received a confirmative answer from Etadunna Station as well as an invitation from the owners, the Oldfield family, to stay at the homestead as long as we liked. This was indeed a most generous offer which we did not hesitate to accept.

Before departing for Etadunna we undertook a few flights in the Cordillo, Betoota and Curalle regions to fill in some gaps left during earlier reconnaissance flights.

On the morning of 25 July we flew from Cordillo Downs to Etadunna. We had been warned that there were a few rabbit warrens on the landing strip, so we made a couple of low passes across it to locate any potential trouble spots. Prior to that we had buzzed the homestead, the usual signal that someone was going to land, and soon after we had touched down Brian Oldfield, the older son of the family, appeared in his Land Rover to take us to the homestead.

Etadunna Station, about 120 km north of Marree, developed from the successive amalgamation of a number of small pastoral leases around the Lutheran and Moravian missions on Lake Killalpaninna and Lake Kopperamanna, respectively. These lakes are part of the flood-out area of Cooper Creek and are filled occasionally, whenever the floodwaters of Cooper Creek obtain sufficient volume. The missionaries were the first white people to settle in the country on the Cooper. The Lutheran mission 'Bethesda' on Lake Killalpaninna was founded by the German missionaries JF Gosling and HH Vogelsang in 1887, only 6 years after Burke and Wills had perished up river near Innamincka. The mission lasted until 1917 (Litchfield 1983).

Jim Oldfield, Brian's father, had taken up the Etadunna lease, now comprising about 4000 km², in 1945 after the place had been abandoned for more than 25 years. There were only ruins left at the place and he and his wife had to build a new homestead which had become one of the finest on the Birdsville Track. It was a large stone building surrounded by a wide veranda, a well kept garden and several out houses.

At the time of our visit Brian's parents and his sister were staying at the homestead in addition to his own family. Life was quite formal; dinner would be served at a set time and everyone was expected to have showered and changed before coming to the table. The spacious living room exuded an air of gracious living which was underscored by a grand piano standing on one side of the room. Rudi, whose mother had been a concert pianist, and who was an excellent pianist himself, took immediate notice of the instrument. Even before sitting down for lunch he had to play a few passages of Chopin's nocturnes.

In the afternoon we surveyed the area around Lake Gregory and Lake Harry, discovering some interesting structures in the surrounding of the latter. On the return flight we spotted rather unusual looking rocks south of Kopperamanna bore. When we mentioned that to Brian he suggested that he would take us to the outcrop next day. However, before attempting to do that we flew north, where we identified a huge structure between Mungeranie and the Warburton. The Birdsville Track was running almost in the middle of it towards Mount Gason bore, thus we termed it Mount Gason Dome. East-west it extended from near Cowarie to the edge of the Sturt Stony Desert.

Accepting Brian's offer from the day before, we set out in the afternoon to inspect the unusual looking rocks southeast of Kopperamanna bore. What we found were cream to yellowish coloured quartzites, or better, medium- to coarse-grained, current-bedded sandstones in a homogeneous quartzitic matrix. Rudi decided immediately that these were rocks of the Adelaide System, belonging to a basement high which had been buried by the Cretaceous marine formations (Fig. 6). Subsequently erosion had removed some of the Cretaceous cover, thus exposing the top of that basement high. At that stage I had not seen a great deal of the Adelaidean rocks and accepted Rudi's interpretation. On the other hand, at the location of the Kopperamanna bore, which was only about 1 km distant from these quartzites, the Cretaceous sequence was more than 1000 m thick and there was still an unknown thickness of Jurassic strata underneath it. I must admit having had difficulties imagining the existence of a 1000 m subterranean mountain or escarpment. Anyhow, we took some samples and returned to the homestead. Less than 12 months later I encountered identical looking quartzites near Blanchewater on the Strzelecki Track containing Tertiary plant fossils; the quartzites were nothing else but groundwater silcretes of Early Tertiary age. The geology of inland Australia was still full of surprises in those days.



Figure 6 Brian Oldfield (left) and Rudi Brunnschweiler (right) at the outcrop of the assumed Precambrian quartzite east of Etadunna. Later the rocks proved to be silicified sandstones of the early Tertiary Eyre Formation.

(Photo 409759)

After dinner that evening Rudi sat down at the piano and played a potpourri of melodies: light classic, operetta, you name it. When he stopped he was urged to continue, especially by the women in the company. Being an extrovert, Rudi didn't need much encouragement to do so. He improvised for a while and then fell into the theme melody of the musical *Carousel* which had been the rage in Europe at that time. Still improvising he started to tell the story, then a few verses of the first song and some more melodies and more explanations of the action, underscored by well placed tunes on the piano and more songs. It took him about 40 minutes to produce that musical single handed; climaxing the performance with the theme song 'Oh my papa was a wonderful man...' Everyone in the room was enchanted and fascinated by that one-man performance. Rudi sat back, accepted a brandy, lit one of his Players Navy Cut cigarettes, and bathed in the adoration of his audience.

On the way back from the quartzite outcrop, Brian Oldfield told us that he hadn't had a chance to inspect the country west of the Birdsville Track where the Cooper Creek entered Lake Eyre. He suspected that a lot of clean skins had wandered off into that part of the country following some local rain showers. It didn't take any more prompting for Rudi: 'That's no problem, I'll fly you there in the morning and you can have a look for yourself'. And so he did. The two of them took off after breakfast and they spotted quite a number of fat cattle along the Cooper. Rudi, what else would you expect, even demonstrated how one could herd cattle with the plane. After we had left, Brian went out there with a mustering team and obtained several hundred fat cattle for the market.

After 4 days flying we finished our survey of the southern margin of the Great Artesian Basin and the area along the Birdsville Track south of Goyder Lagoon. We decided to fly across Lake Eyre to Oodnadatta and visit Santos's Oodnadatta 1 well which was currently drilling. We advised Andy Hess, the wellsite geologist, by telegram of our arrival next day. On arrival I buzzed the camp; Rudi commenting on the perfect bank with which I had encircled the rig before landing at Oodnadatta airport. Andy picked us up and drove us to the wellsite, about 14 km northwest of town. After lunch we inspected some of the drill cores which were quite fossiliferous, containing uncoiled ammonites, nautiloids and a large specimen of the typical Cretaceous bivalve *Inoceramus*. Andy was familiar with them from our collections at Fossil Creek the previous year. He showed us a core of dark green, glauconitic sandstone, which had been intersected below the equivalent of the Wooldridge Limestone, exposed at Fossil Creek. The sandstone contained an abundance of brachiopods which Rudi immediately identified as *Terebratella*. The sands had been barely affected by diagenetic alteration, so

that the insides of the brachiopod shells were still empty, preserving the delicate internal skeleton of the animal. Andy thought that the sand was equivalent to the Mount Bevis Sandstone, which we had used as a marker bed during last year's mapping. Apparently it separated the Albian sequence from the underlying Aptian shale succession with which both Rudi and I agreed. Subsequently the unit was formally defined as Coorikiana Sandstone Member of the Oodnadatta Formation (Freytag et al. 1967) and its position at the Aptian–Albian boundary confirmed by palaeontology (Ludbrook 1966). The 'Terebratella Sandstone' as Rudi named it, yielded some traces of yellow oil and good fluorescence, and on test produced some highly saline water (being more than twice as salty as the ocean) and traces of oil. We also visited the seismic team of the Bureau of Mineral Resources, Canberra, which was carrying out an experimental seismic survey to assist Santos in its exploration efforts. Their work generally confirmed the structural configuration as we had mapped it the year before. Only Mount Alice was no longer a basement inlier as I had thought.

We stayed overnight at the camp in one of the caravans. At around 5 o'clock in the morning we were startled by a nearby blast of a shotgun. We rushed out and almost ran into the Greek cook carrying a shotgun in one hand and a dead crow in the other. Waving the crow victoriously, he approached us with an expression of utter satisfaction and shouted at the top of his voice and in a heavy Greek accent: 'Now I got you, now you squawk you black Australian bastard!'. Apparently the crow had taken a fancy to the aerial wire stretching across the kitchen caravan, waking the cook every morning since the camp had been set up. The cook had countless attempts to kill the bird before, but was always beaten by the cunning of the crow.

On the flight from Oodnadatta across the Simpson Desert we were in for a nasty and rather scary experience. We first flew northnortheast to investigate the Dalhousie structure and then headed straight across the desert for Poeppel Corner. The weather had been warming up lately and as we flew across the desert willy-willies were raising frequently, sending slender funnels of dust almost to our flight level. We were cruising at about 300 m above ground level, so every time we came near one of those whirl winds, the plane bucked and swerved. This wouldn't have been anything to worry about, but every time it happened the left engine cowling lifted up a few centimetres accompanied by a draft of air being felt in the cabin. These were tense and alarming moments. We were afraid that the cowling might come loose altogether and flip up, thus changing the aerodynamics of the plane. It would have made the plane unstable and at least very difficult to handle. The worst we did not dare to think of. In order to minimise the incidence of turbulence acting on the cowling we tried to avoid these up currents or pass them at least on their left side. We were really relieved when we finally reached Birdsville, where we could land. Inspecting the cowling after landing it became clear that the front stud holding the cowling had not been locked properly. I still cringe when I think back that my negligence had been the cause of the problem. I had checked the oil before take-off at Oodnadatta and when I closed the cowling I overlooked that the spring loaded-locking pin, which was somewhat worn out, had not fully snapped into the locking position. Thus it could unlock itself during the flight. Fortunately, the second pin had held. I shudder to think what could have happened if the engine cowling had come off completely. After making sure that this time all the pins were locked properly, we had a quick lunch at the Birdsville Hotel before carrying on to Cordillo Downs.

At lunch we met Mr Brooks, a local grazier, who had commissioned the drilling of an artesian water bore on Adria Downs Station, west of Birdsville. The bore had entered the artesian water-bearing sandstone and was now at about 930 m and nearing completion. Mr Brooks told us that the driller had observed black bituminous matter combined with oil slicks when the drill had entered the water-bearing sandstone. This was highly interesting news and we asked him whether he could provide us with samples. He wasn't sure, but he said he would try.

Preparing for take-off the following morning we noticed that one of the ignition magnetos did not function properly; the reduction of engine revolutions on that magneto was such that even Rudi thought it was beyond acceptable risk. He decided to take it apart and give it a good clean, which we did right at the landing ground. When reassembling the magneto, Rudi dropped a small brass screw. It vanished between the gibbers and the dust, and despite searching on hands and knees for more than an hour we could not retrieve that 3 mm piece of brass. There was nothing else we could do but to reassemble the magneto minus one screw – and it worked, do not ask me how. We decided to survey the Innamincka Dome that afternoon (Fig. 7). There were a number of landing strips at the dome's periphery which we could use should any problem arise. However, the engine ran like a charm and we

carried out about 3 hours of survey work on the structure before returning to Cordillo. At Innamincka we observed again some very clear contacts between the siltstones of the Winton Formation and the basal sandstones of the Eyre Formation, dipping off in sympathy with each other. However, we also observed that the Tertiary thinned out considerably near the apex of the structure, indicating that the dome had already started to grow in the Cretaceous.



Figure 7 Looking west along the escarpment formed by the northern limb of the Innamincka Dome near the South Australian – Queensland border. The boundary between Cretaceous and Tertiary strata is faintly recognisable on the two spurs in the foreground. The plane is just about to sweep down to fly wing tip level with the top of the escarpment. (Photo 047570)

After one more day of flying, investigating the structures along the Wilson River in Queensland, Rudi thought we should return to Adelaide, not stretch our luck too far. It was not only the missing screw in the number 2 magneto. Every time the wheels touched down on landing on the gibber airstrips it was unavoidable that stones were catapulted into the air. Some of them had punctured the fabric of the fuselage and of the elevators. We had 'repaired' the holes with medical adhesive tape, but by the time we had patched up more than half a dozen holes, some of them the size of a fist, it dawned on us that we better seek a more permanent solution.

Dr Brian Daily, Curator of Fossils at the South Australian Museum, together with some American colleagues, was investigating marsupial fossil occurrences along the Warburton and Eyre creeks. They were in Birdsville to replenish their supplies and, when they heard on the Flying Doctor network that we were flying to Adelaide, they asked if we could take some urgent mail with us. We agreed and told them to be at the Birdsville airstrip around 11 am on 2 August. The airstrip was just across the road from the pub and we met Brian and his American colleagues as arranged. They handed over the satchel with letters, the important ones going to the American Research Foundation which was financing most of that expedition. It was the first time that I met Brian Daily and it was the beginning of a friendship which lasted until Brian's untimely death in 1986.

We accepted a glass of lemonade at the bar and then took off for Adelaide. Rudi thought we had enough fuel to get us to Adelaide; there was no need to waste time topping up the tanks. The flight was smooth and uneventful. By the time we reached a position around Gawler all our tanks were empty and we had to switch to the emergency tank which gave us about 15 more minutes flying time. With that we landed safely at Parafield Airport and taxied towards the tarmac and the shack which housed airfield control. We had just reached the tarmac when the engine conked out for lack of fuel.

Including the leg from Cordillo to Birdsville, we had been airborne for 5 hours and 40 minutes; it was quite obvious that we had stretched the Sokol to its absolute limit of endurance.

We had arrived on a Friday and the technicians at Parafield Airport assured us that the plane would be ready on the following Wednesday. When we checked progress of repairs on Monday the technicians were confident to have the plane ready as promised. The engine had been attended to and the holes in the fuselage and elevators had been covered with patches of fabric waiting to be finished with a coat of nitro-solutions once the glue had set.

John Bonython had asked Rudi and me to report directly to him on Tuesday. He wanted to be informed personally about the progress of our survey and quizzed us intensely on our opinion about the hydrocarbon potential of the structures and our plans for the remaining survey. He told us that Dr A.I. Levorsen had contacted a few American oil companies that might be interested to join Santos in its search in the Great Artesian Basin. The more hard facts Santos could present the better its bargaining position. We assured him that we had located more than half a dozen anticlines so far. Each one of them had to be regarded as a potential oil structure, and we were confident that additional structures would be located in the course of the remaining survey.

The following day, Wednesday 7 August, the plane was ready to go and, after a quick shake down flight around Parafield Airport, we departed shortly after noon. We flew again non-stop to Cordillo, but this time without detour, which took us exactly 4 hours and 30 minutes.

The next aim of our survey was the Santos licence area in Queensland. We commenced in its southern part, between Cooper Creek and the southern margin of the Great Artesian Basin near Tibooburra, including the Stokes Range, the Naryilco and Orientos anticlines and the Durham Downs structure. After that we took a day off flying to put our observations onto the map. As we progressed, the map started to reveal an exciting pattern of anticlinal and synclinal structures. What remained now were the eastern and northern portions of Santos's Queensland licence. Using Cordillo as base, we investigated the southern Grey Range and the region between Wilson River, Nockatunga, Plevna Downs and Mount Howitt. On the way back from one of these flights we took a detour to Lake Yamma Yamma which receives water when the Cooper Creek is in flood, but returns its waters to the Cooper after the floods subside. Some additional checks on the Curralle structure were made en route (Fig. 8). On one occasion we had been delayed by refuelling at Windorah and some additional traverses across the Coleman Range. It was almost dusk when we flew the last survey line in the Grey Range. Recalling a previous invitation from the people at Mount Howitt Station to call on them whenever we needed to do so, we headed for their airstrip and landed in the very last light of the day. We were heartily welcomed by the people at the station and spent a most enjoyable evening, being quizzed about any incidental observation which we had made in relation to the conditions of the land we had flown over. As in so many similar experiences, the naturalness and instantaneousness of the generous hospitality of people in the bush was absolutely astounding. Two days later we received a telegram from the Department of Civil Aviation, severely reprimanding us for taking the risk of such a late landing. After finishing the survey of the area around the central and northern Grey Range we focused our attention to the remaining, 'uncharted' area, roughly between Windorah, Davenport and Warbreccan. On 16 August Rudi and I flew our last survey between Cuddapan, Davenport, Curralle and Betoota. On the way I showed Rudi the eastern limb of the Morney Dome, where I had first recognised the unconformity between the Winton and the Eyre formations during the first aerial reconnaissance in April (Fig. 9). It was the last time Rudi and I would fly together (Fig. 10).



Figure 8 Western limb of Curralle Dome looking north. The serpentine shape of the flank of the anticline, which dips 17° to 22° west, is probably caused by shearing. The escarpment formed by the eastern limb is recognisable in the right background. (Photo 409760)



Figure 9 Mount Henderson (left foreground) and escarpments formed by the eastern limb of the Morney Dome. The separation between the Tertiary and the top of the Winton Formation is recognisable on the escarpment behind Mount Henderson. The road from Betoota to Windorah is shown in the left foreground. (Photo 409761)



Figure 10 Rudi Brunnschweiler (left) and Heli Wopfner (right) at Betoota airstrip with the Sokol aircraft, July 1957. (Photo 046049)

Since our return to the region from Adelaide we had spent 42 hours and 25 minutes in the air. Before Rudi left we added the observations of our last flights, thus Rudi could take a finished draft version of the structure contour map with him to Adelaide. We were proud of our achievement (Fig. 11).

On 15 August 1957 the *Advertiser* carried again an article on 'Directors of Santos report...', the last paragraph of which read: 'A good oil showing at 3070 feet [935.7 m] in a newly completed water bore on Adria Downs station south west Queensland has been reported by a Santos party. The aerial geological survey in north eastern South Australia and south western Queensland has established the existence of several new domal structures.'

On 17 August Rudi departed in the Sokol from Cordillo Downs, accompanied by Greg Swindon, to return to Adelaide. Dick Chase, Stan Row and I left Cordillo in our Land Rovers to return to our base at Haddon Downs to continue with the ground mapping and make preparations for the forthcoming stratigraphic drilling program.

Aftermath

Back in Adelaide Rudi added an appropriate legend to the map and had it drawn up under the Santos drawing number SAN 167 (Fig. 11). It became one of the most important documents in the negotiations between Santos and potential American partners. Today, a number of these structures are producing oil fields, like the Jackson field.

Shortly afterwards Rudi resigned from Geosurveys. Sprigg (1993) states in his memoirs that Brunnschweiler had resigned from Geosurveys on 3 August 1957. This date cannot be correct. Rudi and I had reported to John Bonython personally on the results of the aerial survey on 6 August 1957. Surely Bonython would have been informed by Sprigg if Rudi had resigned the week before. On 7 August Rudi and I were both flying back to Cordillo to conclude our survey, and after finishing it Rudi flew back to Adelaide on 17 August, and on 9 September he came to Cordillo Downs again (see above). On none of these occasions was there even a hint of him having resigned. And, finally, in a personal letter written to me by Sprigg from Dallas, Texas, on 30 September 1957, he comments: 'I presume Rudi is having his last day with us today'.

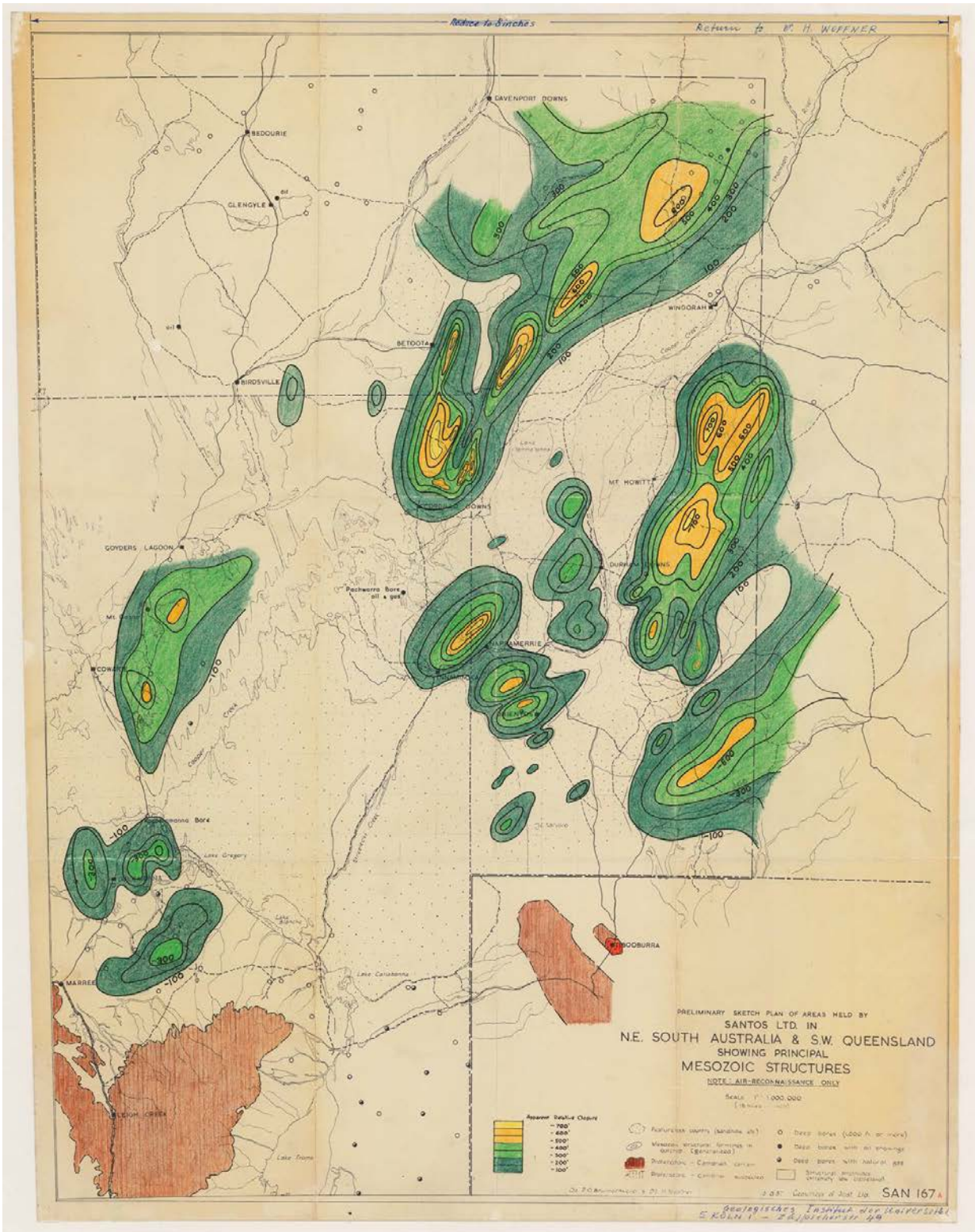


Figure 11 Structure contour map produced by geologists Brunnschweiler and Wopfner in 136 flying hours aerial survey. Titled 'Preliminary sketch plan of areas held by Santos Ltd in N.E. South Australia & S.W. Queensland showing principal Mesozoic structures' and dated 15/8/57.

I had been aware that there had been tension between the two men ever since the Wilkatana project (Wopfner 2010). I also knew that Reg did not approve Rudi taking people from the bush on short flights in the Sokol. I myself had been reprimanded previously for taking Leo Korbet from Alice Springs to the Ooraminna Hills to collect some red sandstone for his garden. On the other hand, such little courtesies were pleasant gestures to show our appreciation for the generous hospitality that we had received. Last, but not least, Reg considered Rudi somewhat arrogant (Sprigg 1993), an opinion which I could not share at all. Neither could I accept the reasons given by Sprigg (1993) for Rudi's resignation. When I returned to Adelaide for reporting in October 1957, Rudi had already left town. He had written a letter addressed to my home at Klemzig in which he told me of his resignation and that he was negotiating for the position of exploration manager with Timor Oil Company. He was quite caustic about Reg Sprigg who had refused to give his permission to publish our structural contour map in an Australian journal under the authorship of Rudi and me. So when Sprigg (1993) states that, 'Rudi refused to join with me in writing an article describing our new finds', it is clearly only half the truth. The prime reason for Rudi's resignation was the refusal to publish the structure contour map under our names, combined perhaps with differences in relation to the forthcoming negotiations with potential American partners in the United States. As far as the publication was concerned, I viewed the situation realistically: I was the employee and Sprigg was the boss. It was his right to decide what material he deemed ready for publication and in what form and by whom it was going to be published.

Apparently Sprigg never submitted the structure contour map to the South Australia Department of Mines, but published it as figure 8 in his paper in the *Bulletin of the American Association of Petroleum Geologists* (Sprigg 1958). What I believe is the only surviving original of the map has been lodged in the archives of the State Library of South Australia (O'Neil 2010).

After the survey the Sokol was due for its 5000-hour inspection. A month or so after the aircraft had gone in to the workshop I met one of the mechanics. 'You guys', he said, 'have been flying on spit and charm. At least 15 per cent of the glued connections of the wooden lattice in wing and fuselage have come unstuck'.

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