Chapter 4. A post-doctoral fellowship at Scripps Institute of Oceanography: 1961-1962.

In August of 1961, I left England for California. I had gone on ahead of my wife and daughter to find somewhere to live. The journey was my first in a commercial jet. When the 707 took off, it soon climbed higher and faster than I had ever experienced in my old military prop driven planes. An old friend from the Fleet Air Arm was one of the pilots. This was before people had started highjacking planes and using them as weapons of blackmail, or mass destruction, and so I got a look at a cockpit of a commercial jet and its navigational systems in action.

The trip also generated my first new Californian friend. He was musician, who knew the group at Scripps Oceanographic Institute, where I was to work. As we took off, I had been chatting with him and when he learnt where I was going, he suggested that I join him at a party at the Raitt's that evening. This was typical of the Scripps environment in those days, where the faculty were always holding parties for students and the whole situation was more like a big family than anything else. The Raitts were particularly generous and always seemed to have students staying with them. My first evening in the new world had produced (shall we say) mild inebriation. Fortunately, the Raitts took me in. Walter Munk and his wife were another couple, who helped make the family atmosphere with their spaghetti dinners and wine. Of course, there were feuds as there usually are among scientists, but it was a wonderful environment for a young scientist, with some of the best geophysicists in the world to learn from and watch in action. Some had already achieved great success and others would later.

Quite a bit of life centered around the magnificent beach and I must admit that part of my post-doc was spent learning how to surf, with only moderate success. I also learnt here not to fool with American police. On one of my first evenings, after we had settled into our little home, I was walking home from a nearby bar after a beer with a friend, when a police car drove up and stopped.

I smiled and said “Good evening”, as I would in London, but clearly this was not going to be an exchange of pleasantries.

“What are you doing?”

“Walking home from the bar up there.” I said pointing in the general direction of the bar.

“You can’t walk here!”

I resisted the temptation to make cute remarks about the land of the free and the like and simply said “Why not?”

“We get a lot of burglaries here. Look at all these expensive houses”.

At this I could no longer resist the temptation to make one of my supposedly funny comments, so I replied. “By the looks of these houses, if I were a burglar I would come in a Cadillac, wouldn’t I”.

The remark was not regarded as funny at all. The two of them jumped out of the car with guns drawn and forced me over the hood and searched me. I don’t think they really regarded me as any sort of threat, but I suppose they were not used to wisecracks from the people they stopped. They soon let me go, but I learnt fast that one did not take American police lightly.

Research at Scripps.

Academic life was more casual in those days than now. I went to America having been awarded a post-doctoral fellowship before my PhD examination. Vic Vacquier and John Belshe were to be my PhD examiners for my oral examination, which would take place at Scripps. The examination was safely negotiated and I began my post-doc work. In those days, post-docs jobs often rapidly transitioned to a full academic post. Later, in more difficult times I would watch my young colleagues in an endless succession of post-docs which did not metamorphose into jobs.

I had come over to California to work with Prof. Vic Vacquier at Scripps Institute of Oceanography. He and Prof. Mason from Imperial College with Art Raff had recently completed magnetic surveys in the Pacific off California and northward. The surveys were made by towing a magnetometer behind the ship in a float, or fish. The magnetometer measured the small variations in the weak geomagnetic field, as the ship crossed the ocean. The work had generated a remarkable result that would turn out to be a key observation - a harbinger of the revolution to come in the earth sciences. The result is shown in figure 4.1. As the ship moved from east to west, it traversed sequences of highs and lows in the magnetic field measured on the ocean surface. The ocean floor must therefore have magnetic highs and lows in this mysterious pattern of roughly north south stripes, that was broken every so often by what appeared to be giant roughly east-west tears in the crust. At this point in the summer of 1961 the origin of this pattern was completely unknown and arguably the biggest puzzle in earth science at that time.

My good friend Chris Harrison was already at Scripps completing his graduate work and so we worked together. The laboratory was a little geodesic wooden hut on a bluff up above the Institute. Regular timed runs, or climbs, up this helped to kept us fit. We had an astatic magnetometer similar to the one we had used at Cambridge and we built more equipment for the susceptibility observations.

During this time, Chris was working on a sediment core that had been recovered from the Pacific. It appeared to have a record of reversals of the geomagnetic field in it and Chris worked this up as a part of his thesis research. This was the first record of reversals in the oceanic sediments. By this time, reversals had been discovered in successions of lavas and in sedimentary sequences on land, but this work marked the discovery of reversals in ocean sediments. Previously cores from the Atlantic studied by Chris Harrison and Mike Keen under John Belshe's leadership had not revealed reversals. The problem with the Atlantic cores turned out to be that the combination of the short length of the piston cores and the fast sedimentation rate where the cores were collected, meant that the recovered sediment did not reach the last reversal. In the deep Pacific Ocean, the sedimentation rates were slower and the cores penetrated to the depth at which the reversals were encountered.

Samples from the Experimental Borehole cores.

We also worked together on material from the Experimental drill hole core. This was part of an effort that later grew into the Deep Sea Drilling Program, then morphed into the Ocean Drilling Program and recently has become the Integrated Ocean Drilling Program. It has involved the work of hundreds of scientists and made fundamental contributions to the earth science of which we will hear much more later. The folklore has it that the idea was hatched at a cocktail party with an initial aim of recovering samples from the mantle of the earth.

If one wanted to reach the mantle why would one got to sea to drill? Surely it would be easier on land. The simple answer was that seismology on land and at sea had yielded the fundamentally important result that the ocean crust was thinner than the continental crust.

Reflection seismology is similar in principle to the method of ultrasonics used in medicine to look at structure in human bodies and to watch babies in the womb. It is also sometimes used in hospitals to search for a deep vein to start IV's, if the patient is a "hardstick" in the terminology of the business. The ultrasonic waves propagate through the skin are reflected from the various internal boundaries, such as the walls of blood vessels. The amount of energy reflected depends upon the miss-match of the velocity of the ultrasonic waves in the materials at the boundary. By timing the arrival of the sonic waves back at the sensor, one can establish the structure beneath. Modern instruments show this as a cross section of the tissues below them, so that one can easily locate the vein and start the IV, or see how the baby is doing in the most well known application of the technique. In a somewhat similar way, in the most popular method of exploration seismology at sea, charges are exploded and receivers records the reflected seismic waves with sensors strung out behind the ship. The boundaries between the different layers of the oceanic crust cause reflections in accordance with the mismatch of the rocks on either side. Again, the results can be presented as a cross section of the earth where the experiment takes place. The method established the structure and thickness of the various layers showing that the boundary between the oceanic crust and the mantle varied, but was frequently only about 5 or 10 kms down.

Exploration seismology had developed from seismology, the branch of geophysics, which deals with earthquakes and the deep structure of the earth. This is the biggest research area in geophysics, delving into the understanding and prediction of earthquakes, as well as the deep structure of the earth and the exploration techniques for looking at relatively shallow structure. It has a long history recounted in many books for the general reader *. In seismology, one uses other methods besides the simple reflection method described above and modern seismology has given us a detailed picture of the deep structure of the earth, illustrated in figure 4.3. This comes from analysis of seismic waves from earthquakes. These can be divided into surface waves that travel along the surface, as illustrated and do most of the earthquake damage, and body waves which travel through the earth.

There are two types of waves that propagate through the earth – primary or push-pull waves (P-waves) and shear waves (S-waves) (fig.4.4). P-waves are like sound waves in that the particles motion is in the direction of propagation of the wave. The wave consists of oscillating rarefaction and compressions that pass through the material. In S-waves, or shear waves, the particle motion is transverse to the direction of propagation (fig.4.4). Unlike P-waves, S-waves cannot travel though fluids. It was this distinction that

---

* Bruce Bolt – Earthquakes, Freeman 1993.

made clear that the outer core, was indeed the likely source of the geomagnetic field. It had also shown that whereas the continental crust was some 30 kms thick, the oceanic crust was much thinner. To get samples of the mantle, it was to the ocean one should go.

Now we had samples from the shallow ocean crust layer beneath the sediments and could measure their magnetization. Our work revealed that the igneous rocks recovered were reversely magnetized as were the sediments immediately above it, which had been apparently baked by the igneous rock. Since the sediments were on top of the igneous rock, it appeared that the magma must have plowed under the ocean sediments at least where we had sampled. If the sediments on top had accumulated in the normal slow fashion, the basalt would have cooled long before much sediment accumulated. At this point then we knew that parts of the ocean floor and some of the ocean sediments were reversely magnetized. They had evidently recorded periods, when the earth's magnetic field was reversed and a modern compass would have pointed south and not north as we see today. Unfortunately, we were not smart enough to see that reversed rocks were the key to understanding Vic Vacquier's mysterious ocean floor magnetic patterns.

Another area in which I was interested was the question of continental drift and whether the evidence that had come from the anisotropy studies was critically important as an explanation of the directions of magnetization recorded. Was the deflection of the remanence by the anisotropy a sufficient explanation of the observed direction, or did one need to invoke movement of landmasses. The effect appeared to be strongest in the redbeds on which much of the paleomagnetic evidence rested. The Permian results were of particular interest and were at that time largely based in America on redbeds. Not far south of where we were near Las Delicias a village near Torreon in Coahuila, Mexico there were supposed to be igneous rocks. These rocks would not be expected to show the same deflection as the redbeds and so it made sense to check the direction found in them and find if it was consistent with the redbed results. A preliminary collection trip was made and I had my first experience of arranging and carrying out fieldwork in a remote area. In the Arctic I had just been a member of a team and more or less simply did what I was told, with the logistics arranged by Peter Friend. Again in Mexico, although we did manage to collect a substantial collection, the results were not convincing.

At about this time I visited Allan Cox and Dick Doell up at the US Geological Survey at Menlo Park. They had by then set up one of the best paleomagnetic laboratories in the USA and were in the middle of their work on reversals. Despite their earlier skepticism of continental drift they were becoming convinced by the results from the English groups and were beginning to accept the drift ideas. They did not think that the results could be explained by the anisotropy that I had found. In contrast at the same time at Scripps, there was not much sympathy with the ideas of continental drift and I remember giving a talk there on the possibility of anisotropy explaining some of the results that had been used as evidence for continental drift, which was well received. It is probably fair to say that many of the more distinguished geophysicists both in the USA and UK competed with each other to show how ridiculous the idea of continental drift was. Among paleomagnetists, John Graham at Princeton had carried out important pioneering work, but now wondered if magnetostriction, the phenomenon of stress affecting directions of magnetization, could account for the results. As the new ideas emerged, they were met by the skepticism that is appropriate in science, but patterns were emerging and before long the evidence would become overwhelming.

Plans to leave the academic world.

Towards the end of the academic year at Scripps I had been looking around for a job and had gone to Pittsburgh to interview at the Gulf Oil Research Laboratory. The research laboratory was an almost academic environment situated outside Pittsburgh at Harmarville in a pleasant campus. When they offered me a job, it seemed like an excellent opportunity and after talking it over with my wife Jean, we decided to take it.

My time at Scripps had been an excellent introduction to the American academic world. It had also taken place in one of the most beautiful places in the world. During my year there, I had also come to understand some of the problems of another America very different from La Jolla. This came largely from friends of the Raitts and in particular those of Martha Raitt, who would later marry Chris Harrison. From them I learnt of planned Freedom Rides. In the England of my youth, there had not been much sympathy for the problems America faced in problems of color. England was still essentially lily-white and had not yet had to face these problems. It was now clear that things were not moving fast enough for many Americans. Little did one guess what the 60's would bring. This was also the time of Friendship Seven and John Glen's ride to fame. Now the nation was fascinated by space and John Kennedy laid down the marker "that this nation should commit itself to achieve the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth".

Pages 9 words 2686

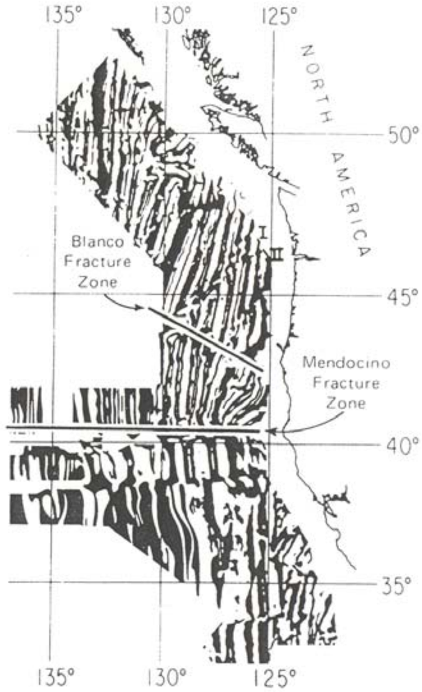


Figure 4.1. Magnetic Anomalies of the North Eastern Pacific.

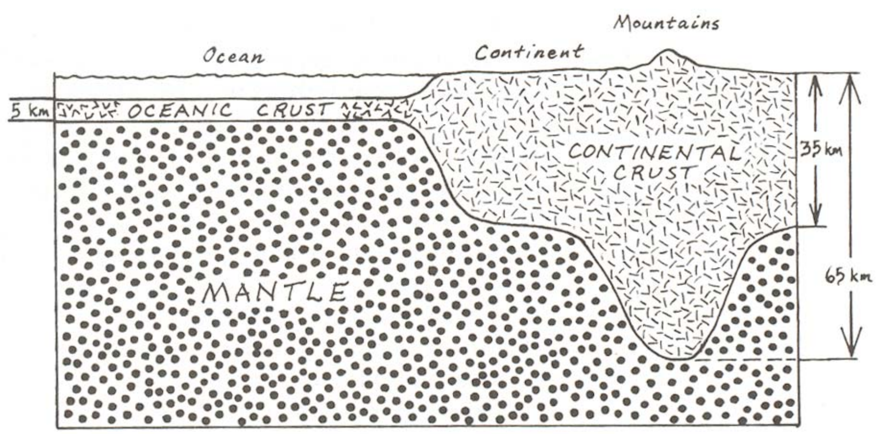


Figure 4.2 Cartoon comparing the thickness of ocean and continental crust.

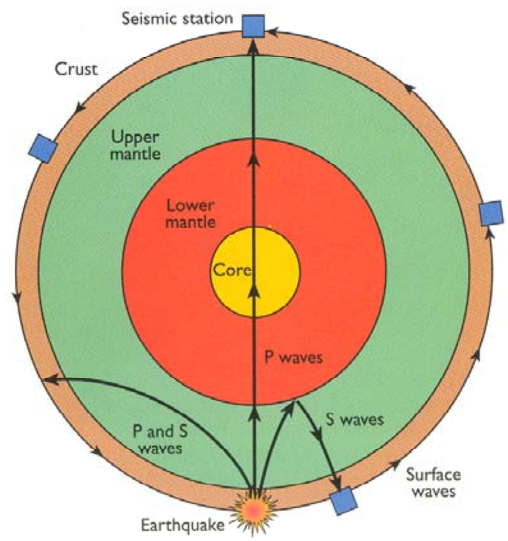
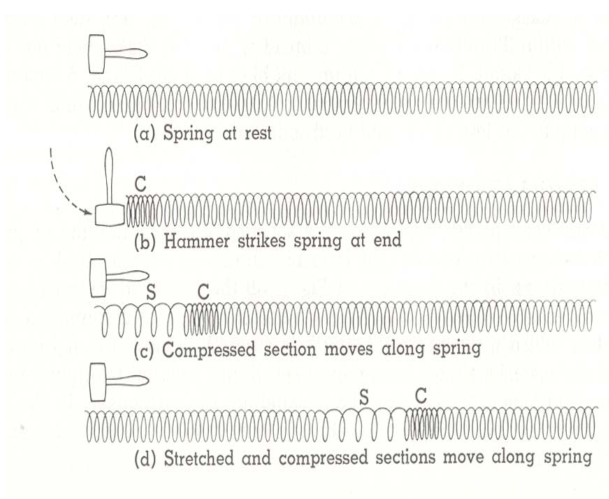


Figure 4.3 Schematic earth structure, showing crust, mantle, liquid outer core and inner solid core.

(A)



(B)

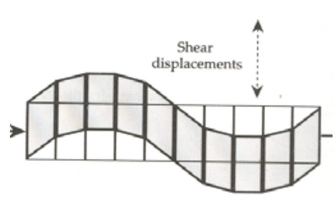


Figure 4.4 Sesimic body waves. (A) p-waves illustrated with slinky toy and (B) shear waves showing displacement of particles is perpendicular to propagation of wave.