

Boston and the History of Biomagnetism

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It is of historical interest that our latest conference, Biomag 2004 (14th International Conference on Biomagnetism), is taking place in Boston. There are two historical events to consider. First, because the initial biomagnetic SQUID measurements were made about 3 km away in Cambridge (in 1969), this Boston area seems to be called "the birthplace of biomagnetism" [Science, 1989], so in a sense we are returning to the birthplace. Second, the first of these conferences on Biomagnetism took place in Cambridge (in 1976), so at this 14th conference we have come full circle, returning to the Boston area where these conferences began. I will here summarize both of these seminal events. But first I'll say something about the biomag period before the 1969 "birth".

THE PRE-SQUID PERIOD (1963-69)

This period began with the first valid biomagnetic recording by Baule and McFee [Baule, 1963], in Syracuse, NY. This was a measurement of the magnetic field of the human heart (the first magnetocardiogram, or MCG); this was recorded outdoors in an open field, far from urban magnetic disturbances. As a detector they used two identical coils connected in series; each contained millions of turns around a ferrite core. These were placed parallel to each other on the subject's chest. The induced currents from a distant background disturbance would presumably be identical in the two coils, hence they would be cancelled. But the heart's field, because it has a gradient over the chest, would produce a net measurable signal. The recording was very noisy, even after signal-averaging, but was indeed valid. In subsequent publications, they also introduced important theoretical concepts into biomagnetics such as the lead-field, and the zero field due to a radial dipole [Baule, 1965].*

This work also stimulated several other groups to use similar coil systems for heart measurements. However, both the magnetic background noise and the intrinsic noise of these crude detectors discouraged widespread interest. In my own case, I had a different approach: using a magnetically shielded room to reduce the background noise. I also used a smaller coil and better amplifier, hence was able to record the



Figure 1. (L to R) Ed Edelsack, myself, and Jim Zimmerman at the MIT shielded room, in Dec. 1969. The first low-noise MCG had been recorded here a day earlier, using Jim's SQUID. "Laurie", at Ed's request, poses as a subject in front of the long-tail glass dewar, which contains the SQUID.

* Baule and McFee did not pursue their work in biomagnetism, but we located Baule for this conference; he was our "mystery guest" at a historical session, and received a big ovation as he spoke about his first measurement.

MCG with far less intrinsic noise, allowing me to study some basic physics of the MCG [Cohen, 1967], also to measure the first crude MEG [Cohen, 1968]. I then moved from Illinois to MIT, in order to expand this work. There I built a good 5-layer shielded room of roughly spherical shape, but was still forced to use a noisy coil as a detector. What was needed was a very low-noise detector, to match the low background noise in this new room. So, in the fall of 1969, the stage was set for this development.

THE FIRST SQUID MEASUREMENT (1969)

I had been hearing rumors about a new superconducting detector, with amazingly low noise. Ed Edelsack, a US Navy funding officer who had given me a small grant, told me that he was also funding the very person to whom I should talk: Jim Zimmerman, who had just invented the SQUID [Zimmerman, 1969]. Ed put me in touch with Jim, and it was arranged that Jim would bring one of his first SQUIDS to my lab at MIT, to look for biomagnetic signals in the shielded room. Jim arrived near the end of December, complete with SQUID, electronics, and nitrogen-shielded glass dewar. It took a few days to set up his system in the room, and for Jim to tune the SQUID. Finally, we were ready to look at the easiest biomagnetic signal: the signal from the human heart, because it was large and regular. Jim stripped down to his shorts, and it was *his* heart that we first looked at. The resulting MCG signal exceeded my best expectations. It was as clear as a conventional ECG, and several orders of magnitude better than the MCG from a coil detector. Although I didn't realize it, a new era had arrived in biomagnetism. The three of us at the scene are seen in Fig.1, and the first MCG trace in Fig.2.



Figure 2. The first MCG, recorded in my MIT shielded room (Dec.1969), using Jim Zimmerman's SQUID. Although not obvious in this old record, the trace was as clear as the conventional ECG. It is signed by Edelsack, Zimmerman, and Cohen.

I then wrote a paper announcing our success, and Jim happily reviewed it and agreed to be co-author [Cohen, 1970]; in my enthusiasm, I also included Edelsack's name, as the facilitator. This announcement was later called the "birth" of biomagnetism in a news review [Science, 1989], because it stimulated the interest of both low-temperature (SQUID) physicists and cardiac physiologists. The main point was that a new physics system (SQUID plus shielded room) was now available for a new, low-noise type of measurement, so that biomagnetism now had a reason to grow.

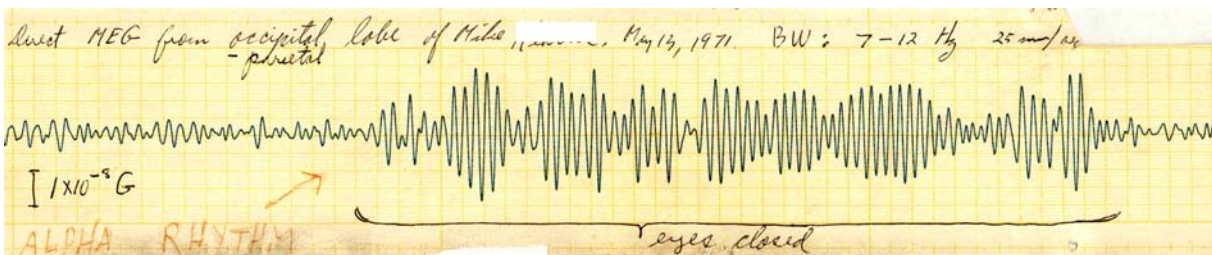


Figure 3. First MEG measured with a SQUID, in the MIT shielded room (May, 1971), using an early commercial SQUID. The subjects eyes were open at the beginning of the trace, then closed, resulting in the large alpha rhythm, then open again. The MEG was now as clear as the conventional EEG.

Later, I made the first measurement of the MEG with a SQUID [Cohen, 1972], now using a commercial SQUID; the MEG measured this way was also beautifully clear (Fig. 3). Other first measurements at MIT followed, including the lungs [Cohen, 1973], and a bit later, the evoked MEG response and the sleep MEG [Cohen, 1975]. These are here mentioned as part of the Boston-area history, but other labs were also measuring their SQUID "firsts". For example, Jim Zimmerman built the first SQUID gradiometer, to be used for biomagnetic measurements without shielding [Zimmerman, 1971]. Toivo Katila and the Finland group, beginning in about 1972, were very active as well, including the recording of the first fetal MCG [Kariniemi, 1974].

THE FIRST BIOMAG CONFERENCE (1976)

As interest in the biomagnetic signals grew, and SQUID measurements spread to other labs in other countries, our research group decided in early 1976 that an international workshop was now needed. Therefore, in August 9-11 of 1976, this first workshop took place at MIT. There were 23 attendees, listed in the table below.

William Barry	USA	Douglas Brenner	USA	David Cohen	USA
Neil Cuffin	USA	Bernard Denis	France	David Farrell	USA
David Geselowitz	USA	Milan Horacek	Canada	Pekka Karp	Finland
Toivo Katila	Finland	Lloyd Kaufman	USA	Makoto Kotani	Japan
Eugene Lepeschkin	USA	Jaakko Malmivuo	Finland	Daniel Matelin	France
Thomas Miller	USA	Martin Reite	USA	Steve Robinson	USA
Gerhard Stroink	Canada	Norman Tepley	USA	Timothy Teyler	USA
John Wikswo	USA	Sam Williamson	USA		

Table 1. Attendees at the first Biomag international workshop (or conference). The seven names in bold are also attendees now, at Biomag 2004.

Of these 23 attendees, three especially cross my mind at this time. The first is Jim Zimmerman, who loomed very large but was *not* there; he was mostly busy with SQUID research, but was nevertheless represented by his colleague Martin Reite. The second is David Geselowitz; he loomed large as perhaps the main biomagnetism theoretician and modeller (the heart), and had contributed the widely-used seminal paper on the forward problem [Geselowitz, 1970]. The third is Sam Williamson; he started out at that time being interested in the MEG, and soon he was a prime mover in biomagnetism and the MEG, especially during the 1980's. His great influence is still felt today.

The subject matter at that gathering was mostly the heart (the MCG), and instrumentation (SQUID); interest in the brain (MEG) was only just beginning. This is reflected in the attendees; out of 23, perhaps 16 were heart researchers, while only 4 or 5 attendees were directly interested in the brain. As I recall, there were no formal presentations as we know them, but only informal workshops in different topics. Of course discussions in this small group spilled over into the social lunches and dinners. The group was small enough so that one of the main social events, a buffet dinner, was held in my home, which was a Cambridge apartment.

Although small in size, this workshop was successful enough so that it became a regular and growing event, held every two or three years. The word "workshop" soon became "conference"; but 1976 was the beginning of these important regular gatherings, whichever word is used. With the 14th conference again in the Boston area, we have come full circle.

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