The untimely death of Charley Hollister in a climbing accident robbed the contourite community of the principal originator and proponent of the concept of deep-ocean current-controlled sedimentation. He possessed boundless enthusiasm, a strong belief that science should be and was fun, a wonderful ability to get disparate groups of people to work together and a fine capacity to see connections between varied strands of data. The latter ability in particular allowed him as a graduate student at Lamont Geological Observatory in the 1960s to put together physical oceanography from Georg Wust, early seismic profiler results from the Ewings, deep-sea photographs, stratigraphic and sedimentological data from cores with his supervisor Bruce Heezen, and develop the notion of sedimentation controlled by deep geostrophic flows.

Charley was born into a landed Californian family whose fortunes were founded on cattle ranching. Eschewing the role of sedate conformity and leadership normally reserved for older sons, his boyhood was, by his own account (thoroughly confirmed by his family), happily irresponsible. His schooling was chequered and his undergraduate academic performance at Oregon State University undistinguished. However, although his best developed abilities were as a marksman and mountaineer, late in the day the spark of what he really wanted to do struck. Doc Ewing, director of Lamont was persuaded that Charley’s enthusiasm once channelled, could lead to a successful career as a marine geologist and admitted him to the graduate programme in 1960.

In the late 1950s ideas about the deep circulation developed rapidly with Wust’s (1955) recalculation of geostrophic velocities, Swallow & Worthington’s (1957) demonstration of high flow speed in the Western Boundary Undercurrent, and Stommel’s (1958) proposal of a scheme for the deep sea circulation. These new ideas were quickly picked up by Charley’s supervisor Bruce Heezen who wrote in 1959 ‘... it would appear that the deep ripples and bottom scours must be the work of currents related to the general circulation of the ocean ...’. However, a strong emphasis was then placed on the continental rise and abyssal plains displaying features originating in turbidity current flow. Hollister assembled the photographs showing current bedforms corresponding in location to Wust’s predicted strong abyssal flows in the South Atlantic and convinced Heezen of the importance of current reworking of the continental rise. This became Hollister’s topic for a PhD dissertation and he turned to examination of further evidence in photographs and cores for bottom currents, finding a positive result at several other deep locations where Wust had predicted rapid flows, particularly the western North Atlantic (Heezen & Hollister 1964). Wust’s presence at Lamont through this period (1960–1964) acted as a great stimulus to the task. This work culminated in the proposal that the deep western boundary current was responsible for most of the deposition on, and form of, the eastern United States’ continental rise (Heezen et al. 1966). The importance of turbidites was explicitly denied, ‘... recognisable turbidites constitute a small proportion of the glacial and postglacial sediments of the continental rise’ (Heezen & Hollister 1964). Those statements underplay the clear recognition by the authors that they were dealing with terrigenous sediments which had come downslope, probably in turbidity currents. The argument really lay in the degree of completeness to which the turbidites were reworked and deposited as contourites.

There was by now a large collection of cores from the continental margin, and the development in 1961 of seismic reflection profiling by John Ewing at Lamont had yielded several hundred thousand miles of data by 1964 (Ewing & Ewing 1964). In these data were the striking profiles of the Blake Outer Ridge showing it to be 2 km of deep-sea sediments at a location where turbidity current emplacement was impossible. There was thus abundant data on the sediment characteristics and distribution of contourites as is made clear by figures 1 and 3 of Heezen et al. (1966). This paper was rapidly followed by others from Heezen’s group consolidating their position that sediment transport in contour currents was responsible for much of the sedimentary topography of the American Basin, and by Charley’s PhD thesis (Hollister 1967) a significant part of which is in Hollister & Heezen (1972). It was in the latter paper that the term ‘contourite’ was first defined, though it had already been in conversational use for a while.

A new source of data added by Hollister (1967; Hollister & Heezen 1972) was the 12 kHz echogram character of the bottom.

This new development of 'echo-character mapping' by Hollister was greatly expanded in the following decade using the now ubiquitous 3.5 kHz profiler. The 12 kHz system revealed contour-parallel variation on the continental rise with poorest reflectivity [hyperbolae and indistinct ('mushy') echoes] in the location of supposed maximum bottom current. The variation was suggested to be due to variations in microtopography. A superb book of photographs with linking narrative by Bruce & Charley The Face of the Deep (1971) showing this microtopography was a further product of their collaboration. It remains the best published collection of deep-sea photographs, but sadly is long out of print.

Many questions relating to sedimentation and the genesis of echo character could be answered only by a closer look. Charley was quick to realise the potential offered by the Scripps deep-tow system (Spiess & Mudie 1970; Spiess & Tyce 1973). The deep-tow gave side-scan sonar and 4 kHz reflection profiles of a quality comparable to that used by workers on continental shelves where these techniques were commonplace. In addition, twin 35 mm cameras allowed stereographic resolution of the dimensions of smaller features. The principal elements of microtopography surveyed were ripples, sand dunes and furrows as well as mud waves which were also studied via surface ship 3.5 kHz records. Most records produced great surprises from ripples in mud to barchan dunes of sand to extensive fields of linear furrows (Hollister et al. 1974, 1976; Lonsdale & Spiess 1977). The furrows appeared to be part erosional, part depositional and pointed to the possibility of helical secondary circulation in the bottom mixed layer proposed by Charley's student Roger Flood (1978).

Furrows were also found to be responsible for hyperbolae echoes mapped previously. This closer look also involved him in physical oceanographic measurements in relation to large scale sediment bodies and the deep Western Boundary Undercurrent (WBUC). Geologists often had to conduct the physical oceanographic investigation of the flow setting in relation to bedform development, a fact with which he used to upbraid his P.O. colleagues at WHOI who at that time did not set current meters deeper than 4000 m, even where depth was 5000 m.

Staff at Lamont, particularly Maurice Ewing, were instrumental in establishing the Deep Sea Drilling Project with Leg 1 in 1968. Although a recent PhD, Charley sailed on Leg 11 in 1970 as Co-Chief Scientist with John Ewing. Everything was new then, and they found the cherts producing the Horizon A seismic reflector, stacks of contours and the Mid-Cretaceous black mudstones. At the end-of-leg press conference in New York Charley made the point about carbon content by setting a piece alight. He always knew how to get attention. The first attempt at reconstruction of the palaecirculation of the Atlantic in a series of palaeogeographic maps from Jurassic to recent in Berggren & Hollister (1974) was a seminal product of his Atlantic drilling work. DSDP Leg 35 to the inhospitable Bellinghausen Sea of the SE Pacific in 1974 was his last drilling leg, for other things had started to occupy him.

Standard piston cores of 6 cm internal diameter (i.d.) do not provide much material to work with and sidewall deformation generally distorts sedimentary structures. So early in his career at Woods Hole (which he joined in 1967 after an interlude climbing the high peaks of Antarctica) Charley conceived of the Giant Piston Corer. This involved a very large weight and pipe that held 10 cm i.d. liner (compared with the 6 cm then current, giving three times the volume of material). Gradually, in an experimental process that involved destroying much ships equipment; cables, shearing etc., and leaving many GPC's in the sea bed as a result of these failures, the system was brought to an operational state. The cores obtained were of stunning quality and those from the Central Pacific (GPC-3), Bermuda Rise (GPC-5) and Bahama Outer Ridge (GPC-9) are still being sampled, and at the hands of Lloyd Keigwin and Ed Boyle paved the way for modern high-resolution palaeoceanography.

Today's IMAGES programme using a 7.5 ton corehead and 11 cm i.d. liner, but with modern Kevlar cable, owes much to Charley's foresight.

This development was rather expensive, particularly in view of the amount of hardware destroyed or left on the sea bed, so it was fortunate that he had stumbled on a new funding source when it had not previously had dealings with oceanographers. A chance meeting in Washington in the early seventies led to the investigation of what he liked to call 'the least valuable real estate on earth', the mid-gyre deep-sea bed, for disposal of high-level radioactive waste. He became aware that the Washington agencies in need of answers to problems of waste disposal had substantial budgets. It was also very clear to him that investigation of this problem would be very expensive indeed! The project was to examine the feasibility of, and problems associated with, subsurface disposal of 'hot' nuclear waste. If waste canisters or projectiles were to be emplaced below the sea bed, feasibility would partly depend on the geotechnical properties of the bed. Soil mechanical tests needed larger samples than were available from small diameter piston cores. Charley had the imagination to see that this was a heaven-sent opportunity to mount a multi-faceted approach to problems of the deep-sea environment while also funding his equipment developments.

This project, run through the Department of Energy's Sandia Laboratories, involved a large amount of work on seismic profiling, sedimentology, biology, micropalaeontology, stratigraphy, minerology, modelling, and science policy studies of the deep sea bed. The work culminated in an authoritative paper in Science in 1981. Charley was, when among scientists, a disinterested observer concerned mainly with maximizing research income for important investigations of the deep sea environment in connection with a very significant societal problem. There were times when he appeared to be advocating deep sea disposal and this made him the target for the more politically motivated commentators in environmental organizations. Much good science came out of the Sandia project and Hollister recognized at an early stage that environmental policy studies had to be conducted alongside the scientific work. Technical feasibility and safety might be demonstrated, but projects could, and frequently still do, fall on politically motivated campaigns of scientific misinformation.

The final major science project led by Charley Hollister was HEBBLE, the High Energy Benthic Boundary Layer Experiment funded by the US Office of Naval Research. In 1974 I organized the NATO Conference on the Benthic Boundary Layer at the skiing resort of Les Arcs at which Charley was an invited keynote speaker (McCave 1976). He saw that his interests in current-controlled sedimentation and bedforms could be given full expression under the banner of boundary layer research and found a ready ear in Tom Pyle, program manager at the ONR. (He was also delighted to find that his interest in mountains and skiing could so easily be fitted under 'oceanography', that he took our lesson of Les Arcs and repeated it many times for HEBBLE at Keystone, Colorado). After a few exploratory meetings and probing possible experimental areas we assembled an executive committee and fixed on the lower Nova Scotian rise as the experimental site. It was probably not accidental that this was both part of Charley's original thesis area, and that it lay under the main path of Soviet submarines (and aircraft who often inspected us) down the US east coast to Cuba.

In seeking the simplest type of boundary layer for HEBBLE it was decided to try and avoid areas of furrows and longitudinal ripples with possible helical circulations, and mud waves which might have associated standing internal waves (Flood 1978), but nevertheless investigate an area where dynamic processes of erosion and deposition were well developed. As with his previous projects, HEBBLE assembled geologists, geochemists, biologists, engineers and physical oceanographers focussing on flow-bed interactions considered very broadly. The results came out in two special issues of Marine Geology, and many other publications, totalling over a hundred papers. The ideas of deep-sea storms,
turbulence in a planetary boundary layer, nepheloid layers, bioturbation, benthic habitats, sediment sorting, and many other matters bearing on the formation of contours were probed more deeply and revealingly than ever before in the field.

Early on in HEBBLE, Charley moved from being a Senior Scientist in the Department of Geology and Geophysics to taking charge of the institution’s graduate program as Dean of Education and an Associate Director of WHOI. Although he sailed on most of the cruises and took an active interest in steering all the aspects of HEBBLE, and particularly in stereophotogrammetry of the sea bed, he was increasingly occupied in matters of educational policy and science policy more generally. The end of HEBBLE in 1987 really saw the end of Charley’s active involvement in experimental science, and in 1989 after ten years as Dean of the Graduate Program, during which he had come to understand very clearly that the education program was in dire need of endowed funding, he took his final position at Woods Hole as Vice-President of the Corporation and Associate Director for External Affairs in charge of fund raising and communications. In this, as in his marine geological activities, the combination of enthusiasm and a deep love of the subject, coupled with a vital objective, the survival and enhancement of the quality of the Woods Hole Oceanographic Institution, proved most successful and WHOI has been enriched in many ways by his activities.

Those of us who were his principal collaborators and friends, evident from his publication record given below, have felt a deep sense of loss. The wider world of those concerned with the interplay of the cruises and took an active interest in steering all aspects of the Face of the Deep. Oxford University Press, New York.


Scientific Publications of C. D. Hollister


FLOOD, R. D., HOLLISTER, C. D., JOHNSON, D. A., LONSDALE, P. F. &...


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