The Falkland Islands: Goal-Directed vs. Open-Ended Discovery

Thomas F. Shipley[1] and Basil Tikoff*,[2]

Geology logline: *Both Alexander du Toit and Charles Darwin made scientific advances when studying the Falkland Islands, the former effectively demonstrating continental drift.*

Cognitive science logline: *The mind at its best engages in both goal-directed enquiry and curious exploration, and the two modes have different mechanisms and functions.*

> *"In every walk with nature one receives far more than [one] seeks."*
> ***—J. Muir (1877)***

The Falkland Islands are located at 52° S latitude in the southern Atlantic Ocean, ~500 km east of southern Argentina, 1200 km north of the Antarctic peninsula, and 6500 km west-southwest of South Africa (Fig. 1). The archipelago was part of Gondwana. The rocks include Carboniferous tillites and contain fossils of clear Gondwanan affinity. The islands were visited by two extraordinary geologists, ninety years apart: Charles Darwin and Alexander du Toit. These two scientists had very different goals, scientific styles, and funding mechanisms. As a result, they epitomize two end-member models for how science is done.

Darwin arrived in the Falkland Islands in 1833. To say that he was not attracted to the landscape would be an understatement. He wrote: "An undulating land, with a desolate and wretched aspect, is every where covered by a peaty soil and wiry grass, of one monotonous brown colour" (Darwin, 1846, p. 245). Also, consider this gem of what-not-to-put-in-a-travel-guide: "The weather was very boisterous and cold, with heavy hailstorms. We got on, however, pretty well; but excepting in the Geology, nothing could be less interesting than our day's ride" (Darwin, 1846, p. 246). Yet, Darwin goes on to recognize asymmetrical folding (i.e., fold vergence; Fig. 2), geomorphic features ("stream of stones"),

*basil@geology.wisc.edu
[1]Temple University, Philadelphia, Pennsylvania 19122, USA
[2]University of Wisconsin–Madison, Madison, Wisconsin 53706, USA
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Devonian fossils (e.g., Stone and Rushton, 2024), and all sorts of organisms (geese, sea slugs, etc.). He speculates on all of them. For example, he contemplates why the Paleozoic fossils are so similar to those in England, even though the creatures living there today are so different. What you can tell is that he is thinking—about everything. Darwin published an article on the geology of the Falkland Islands (Darwin, 1846), and it forms a chapter within his 1839 book, The Voyage of the Beagle (Darwin, 1839).

Alexander du Toit came to the Falkland Islands (and eastern South America) in 1923 as a person on a mission. Alfred Wegener had recently published his book arguing for continental drift (1915 in German; English version in 1921). His basic argument was that the shapes of the continents and the distribution of fossils, particularly in the southern hemisphere, match very well if the two continents were moved back together (Fig. 1). Fossils from the Falkland Islands, including those found by Darwin, were part of the evidence that Wegener used to advocate for continental drift. If the landmasses were once contiguous, then the geology—in addition to the fossils—should be compatible. Despite nearly universal rejection of the continental drift hypothesis in North America, the Carnegie Institute of Washington, DC—due to the influence of Reginald Daly of Harvard University—was willing to fund a geological mission to South America to determine if continental drift could be correct (see Oreskes, 1999).

Du Toit was one of the foremost experts in the geology of South Africa. Both du Toit and Wegener noted that the fossil record is insufficient to prove continental drift because the data can be explained by alternative hypotheses (moving continents or the rise and fall of land bridges). During his fieldwork, du Toit documents two additional compelling lines of evidence to support continental drift. The first is that the stratigraphy of the Falklands Islands and South Africa are nearly identical, and both are similar to the stratigraphy in South America. This is du Toit's most fundamental insight: The striking stratigraphic similarity makes a case that the regions were adjacent. The second line of evidence involves the EW-trending Cape fold-thrust belt with asymmetric folds indicating northward vergence (Fig. 2). This belt crosses into South America exactly where it would project from South Africa if the continents were restored (Fig. 3). Asymmetric folds are also found on the Falkland Islands, but with an opposite direction of vergence (southward; see below) and are located significantly south of the equivalent features on South Africa and South America. To explain this observation, du Toit restores the Falkland Islands to the north relative to their current position (Fig. 3). The data provided by du Toit are compelling: The continents must have moved relative to each other. This conclusion is given in the book A Geological Comparison of South America with South Africa (du Toit and Reed, 1927), with the results incorporated into Our Wandering Continents (du Toit, 1937).

The cognitive theme of this essay is the contrast between two modes of attention, also referred to as modes of

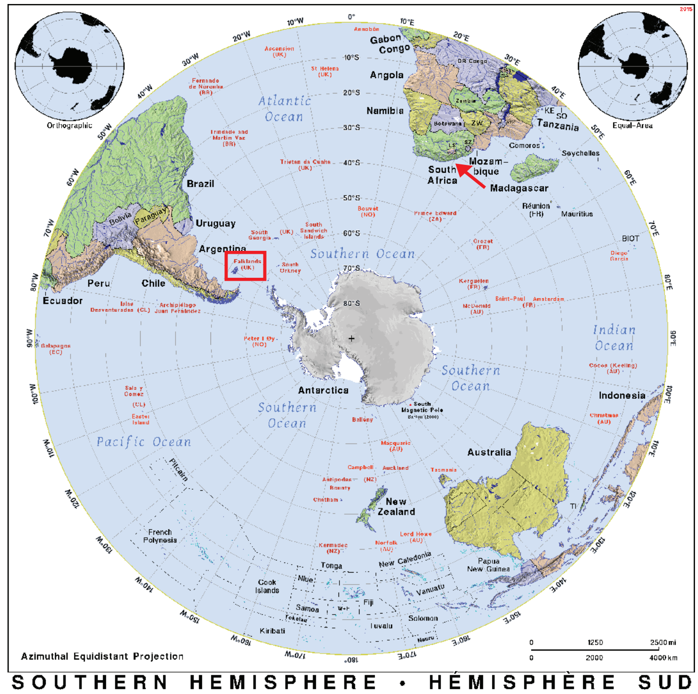

Figure 1. The polar view of Earth, showing the location of the Falkland Islands (red box) with respect to southern South America and southern Africa. The red arrow shows the approximate location that the Falkland Islands restore to prior to Gondwana rifting. Credit: Ian Macky, https://ian.macky.net/pat/map/shem/shem.html.

consciousness, exhibited so well by Darwin and du Toit: spotlight mode and lantern mode (Gopnik, 2009). A spotlight provides bright illumination in a small area, and that area is surrounded by darkness. Spotlight mode (think about du Toit) occurs when one is answering a specific question and focuses attention on only the aspects of the world that are relevant to achieving an answer to that specific question. The upside of focused attentional resources is that learning can advance quickly. The downside is the learning is typically narrow, meaning the learned solution applies to the case that generated the goal, but may not generalize well. A lantern, in contrast, provides dimmer illumination, but provides it everywhere. Lantern mode (think about Darwin) refers to diffuse attention, meaning that the individual is open to all potential inputs in the world around them. The advantage of this mode is there is no filtering by preconceived ideas about what is important. The disadvantage is that learning may be slow and progress hard to see or feel. It has been argued that children use lantern mode to learn a language; this mode is necessary to extract a language's complex grammatical rules from speech, given all the ways that meaning is conveyed by grammar in the world's languages (Gopnik, 2009).

These modes of attention have different functions, and there is significant benefit to moving back and forth between them. In spotlight mode, exemplified by du Toit, behavior appears generally work-like, familiar in the pursuit of hypothesis-driven data collection. In lantern mode, modeled by Darwin, behavior is more play-like and exploring occurs in response to curiosity without specific aim. To a goal-oriented observer, a scientist in lantern mode can appear unproductive.

Psychologists have argued that deep learning requires both goal-directed and playful interactions with the world (Gopnik, 2009). Goal-directed attention is optimal for refining knowledge about something that is well understood, to fill in missing pieces or collect information that will improve understanding to serve a purpose. In contrast, when confronted with something wholly new, robust learning is better achieved through exploring and interacting with the problem without a singular goal. Goal-directed attention, as occurs in spotlight mode, is ill-advised in this situation, as one is likely to focus on some aspect of a situation that is marginal. The resultant learning is likely to be brittle, not serving the learner when the situation changes slightly.

The modes also have different brain mechanisms, which contribute to different types of learning and manifest themselves as different overt behaviors. Two functionally distinct networks in the brain organize activity that aligns with the two modes of attention. The fronto-parietal network is active when working on a problem using focused attention, as occurs in spotlight mode. This network spatially restricts processing and is engaged for working memory tasks, where memories necessary for a task are actively maintained (Menon, 2011). Direct, focused attention on a problem, such as, "Are the rocks in the Falkland Islands similar to the rocks in South Africa?" will be answered in spotlight mode. The fronto-parietal network boosts processing in local regions of visual space (and the conceptual space of similar concepts), making things in that region more salient and surrounding things less salient (Menon, 2011). Solutions found in spotlight mode are likely to be a conceptually proximal solution. The problem with spotlight-mode solutions is that, although they are often locally optimum, they can be globally poor. We hypothesize that the assumption of simplicity is a product of a spotlight mode of thinking, which is neither the only way a problem can be solved nor necessarily the optimal way to solve a problem (see Tikoff and Shipley, 2025).

These problems of spotlight mode can be illustrated from the history of determining the tectonic reconstruction of the Falkland Islands. To explain why the Falkland Islands contain the EW-trending Cape fold-thrust belt with its asymmetric folds, du Toit and Reed (1927) restored the Falkland Islands northward prior to breakup of the continents. The issue is that the southward fold vergence in the Falkland Islands (Fig. 2) is inconsistent with the northward fold vergence of the Cape fold-thrust belt (Fig. 3). Most modern reconstructions, following Adie (1952), place the Falkland Islands on the east side of South Africa prior to Gondwana breakup (Fig. 3). This reconstruction includes a 180° rotation of the Falkland Islands as they moved as a micro-plate around Cape of Good Hope in southernmost Africa, which allows the repositioned Falkland Islands to

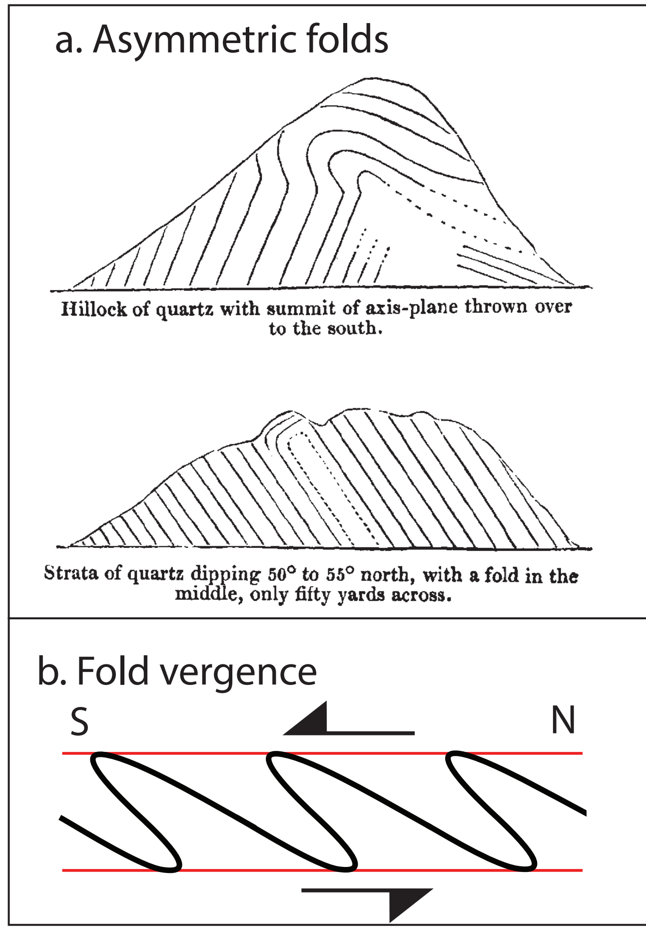

Figure 2. (A) Two sketches from C. Darwin of asymmetric folding in the Falkland Islands, which formed as part of the Cape fold-thrust belt in South Africa (from Darwin, 1846, p. 272). (B) A cartoon of idealized fold vergence shown in a vertical cross section.

have the same (northward) fold vergence as the Cape fold-thrust belt. Note that neither du Toit or Adie knew about transform faults, which provide an independent constraint on the direction of motion between Africa and Antarctica. Adie's reconstruction is neither the shortest distance nor simplest solution, but it fits with the constraints of the data. Scientists usually choose the simplest possible solution, particularly when working in spotlight mode. This inference is consistent with this sentiment:

"... subjected to the principle of least astonishment, geologic science has always tended to adopt the most static interpretation allowed by the data, and evidence indicating displacements larger than conceivable . . . has consistently met strong resistance" (Seeber, 1983, p. 1528).

The reason, in part, is that working "efficiently" typically involves dealing with proximal causes.

Cognitive science research offers an intriguing perspective on thinking about geological displacements. Locations in real space are represented in the brain in such a way that greater distances between locations correspond to

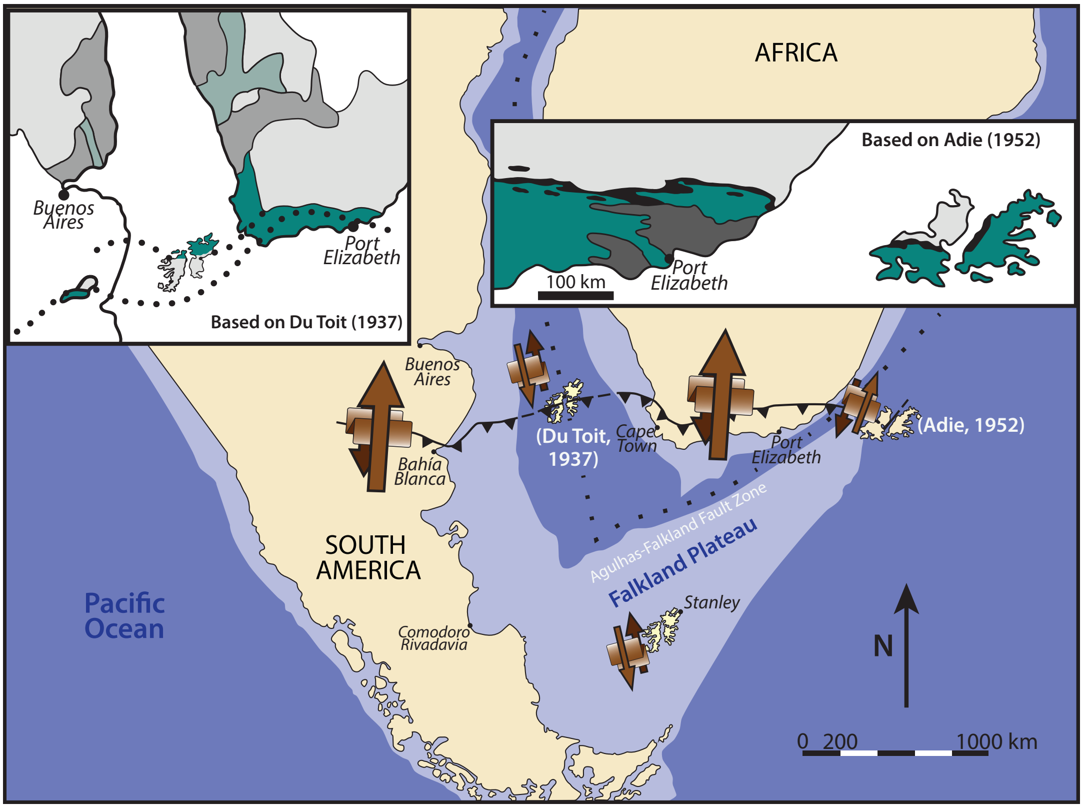

Figure 3. Two possible locations of the Falkland Islands prior to the rifting of Gondwana, based on du Toit (1937; following du Toit and Reed, 1927) and Adie (1952). The brown arrows indicate the direction of fold vergence, as shown by folds. The thrust fault demarcates the extent of the orogenic front associated with the Cape fold-and-thrust belt in Africa. Du Toit reconstructs the Falkland Islands straight northward, in order to place them on the trend of the Cape fold-and-thrust belt in South Africa and its equivalent in South America. Adie reconstructs a slightly longer and curved path, to place the Falkland Islands adjacent to the Cape fold-and-thrust belt on the eastern side of South Africa. The Adie (1952) reconstruction is generally accepted, although it requires significant rotation, in addition to longer translation, of the Falkland Islands. Figure modified from Ramos et al. (2017).

greater distances in the brain. In some cases, it is a physical distance (Knudsen and Konishi, 1978); in other cases, it is a similarity in network activity (Morgan et al., 2011). Consider this finding from a functional magnetic resonance imaging (fMRI) study:

"fMRI response levels in the left hippocampus corresponded to real-world distances between landmarks shown on successive trials, indicating that this region {of the brain} considered closer landmarks to be more representationally similar and more distant landmarks to be more representationally distinct" (Morgan et al., 2011, p. 1238; text in parentheses are our addition).

That is, distant parts of the brain tend not to communicate with each other, with connections dropping off with intra-brain distance as a power function (Iturria-Medina et al., 2008). To return to geology, the connectivity suggests that a representation of a long curving path connecting past location to present location (e.g., reconstruction of Adie) is less likely to occur in the brain than a short, straight path (e.g., reconstruction of du Toit), and consequently will be less likely to be thought.

A different network of circuits, the default mode network, appears to be engaged in lantern mode. The default mode network is active for a range of mental activities including daydreaming, watching movies, listening to stories, and recalling specific incidents from one's past. All of these activities involve events and some narrative (Simony et al., 2016). The default mode network is active when not working with focused attention. The details of how the mind connects far things in the brain are currently unclear. However, there is a functional value to connecting far-apart ideas in the world. Such connections could move important relationships, which are highly dissimilar on the surface but share a common deep structure, to the foreground.

Forming such distant connections typically does not occur with focused attention. Inspiration—flashes of insight into how to solve a challenging problem or reconceptualize a model to fit data—typically come as solutions to problems you were not conscious your mind was working on. After the initial insight in lantern mode, work in spotlight mode can "backfill" the connection for conscious articulation of the underlying logic.

The goal-directed approach of spotlight mode will likely seem familiar to many readers, particularly those actively engaged in trying to fund research projects where clearly stated goals and explanations of how to meet those goals are expected. Yet, play-like, exploratory research happens at both a community scale and at an individual scale. The 2003–2018 EarthScope program, funded by the National Science Foundation, was largely exploratory science, using seismology to make a map of the mantle below the United States and some parts of adjacent Canada (Meltzer, 2003). Individual scientists may engage in play-like investigations. At any given time, scientists may have an unfunded side project in which they are fascinated by an idea or a set of observations. Each of the authors has a couple of ongoing side projects that are unfunded and do not advance a major research objective, but our history tells us these side projects often move to the foreground when they yield surprising new data or ideas.

Some psychologists have argued that lantern-mode attention is primarily available to children, whereas adults only occasionally slip into this mode (Gopnik, 2009). In our casual conversations with other scientists, it seems that interdisciplinary science involves the occasional lapse into lantern mode, particularly for ideas that cross traditional boundaries and require mental permeability. Retrospectively, we see that our work on these essays required a cycle between lantern and spotlight modes.

Both spotlight and lantern modes yield discoveries. Spotlight mode efficiently fleshes out models and effectively tests specific hypotheses; it keeps research programs on track. Theories that come out of lantern mode are likely to be novel, connecting ideas that had not been part of the standard approach in an area. Lantern mode is more likely to provide conceptual breakthroughs. Knowing these endmember approaches, and how they were used in the Falkland Islands, a person would do well to both work assiduously like du Toit and wander curiously like Darwin.

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REFERENCES CITED

***denotes suggested further reading**

Adie, R.J., 1952, The position of the Falkland Islands in a reconstruction of Gondwanaland: Geological Magazine, v. 89, p. 401–410, https://doi.org/10.1017/S0016756800068102.

Darwin, C.R., 1846, Geological Observations on South America: Being the Third Part of the Geology of the Voyage of the Beagle, under the Command of Capt. Fitzroy, R.N. during the Years 1832 to 1836: London, Smith Elder and Co.

Darwin, C.R., 1839, The Voyage of the Beagle: London, Henry Colburn.

du Toit, A.L., 1937, Our Wandering Continents; A Hypothesis of Continental Drifting: London, Oliver & Boyd, 366 p.

*du Toit, A.L., and Reed, F.R.C., 1927, A Geological Comparison of South America with South Africa: Washington, D.C., Carnegie Institution of Washington, 188 p.

*Gopnik, A., 2009, The Philosophical Baby: What Children's Minds Tell Us about Truth, Love, and the Meaning of Life: New York, Farrar, Straus and Giroux, 304 p.

Iturria-Medina, Y., Sotero, R.C., Canales-Rodríguez, E.J., Alemán-Gómez, Y., and Melie-García, L., 2008, Studying the human brain anatomical network via diffusion-weighted MRI and Graph Theory: NeuroImage, v. 40, no. 3, p. 1064–1076, https://doi.org/10.1016/j.neuroimage.2007.10.060.

Knudsen, E.I., and Konishi, M., 1978, A neural map of auditory space in the owl: Science, v. 200, no. 4343, p. 795–797, https://doi.org/10.1126/science.644324.

Menon, V., 2011, Large-scale brain networks and psychopathology: a unifying triple network model: Trends in Cognitive Sciences, v. 15, no. 10, p. 483–506, https://doi.org/10.1016/j.tics.2011.08.003.

Meltzer, A., 2003, EarthScope: Opportunities and challenges for earth-science research and education: The Leading Edge, v. 22, no. 3, p. 268–271, https://doi.org/10.1190/1.1564533.

Morgan, L.K., Macevoy, S.P., Aguirre, G.K., and Epstein, R.A., 2011, Distances between real-world locations are represented in the human hippocampus: Journal of Neuroscience: v. 31, no. 4, p. 1238–1245, https://doi.org/10.1523/JNEUROSCI.4667-10.2011.

Muir, J., 1877, Mormon Lilies: Liliaceous Wonder-A Mountain Covered with Flowers Gorgeous Lily Gardens-A Sublime Scene-The Queen of All: Special Correspondence of the Bulletin, Daily Evening Bulletin, San Francisco, 19 July 1877.

Oreskes, N., 1999, The Rejection of Continental Drift Theory and Method in American Earth Science. Oxford, UK, Oxford University Press, https://doi.org/10.1093/oso/9780195117325.001.0001.

Ramos, V.A., Cingolani, C., Chemale, F., Naipauer, M., and Rapalini, A., 2017, The Malvinas (Falkland) Islands revisited: The tectonic evolution of southern Gondwana based on U-Pb and Lu-Hf detrital zircons isotopes in the Paleozoic cover: Journal of South American Earth Sciences, v. 76, p. 320–345, https://doi.org/10.1016/j.jsames.2016.12.013.

Seeber, L., 1983, Large scale thin-skinned tectonics: Reviews of Geophysics, v. 21, no. 6, p. 1528–1538, https://doi.org/10.1029/RG021i006p01528.

Simony, E., Honey, C.J., Chen, J., Lositsky, O., Yeshurun, Y., Wiesel, A., and Hasson, U., 2016, Dynamic reconfiguration of the default mode network during narrative comprehension: Nature Communications, v. 7, https://doi.org/10.1038/ncomms12141.

Stone, P., and Rushton, A.W.A., 2024, Charles Darwin's discovery of Devonian fossils in the Falkland Islands, 1833, and its controversial consequences: Geological Society of London Special Publication 543, p. 205–216, https://doi.org/doi:10.1144/SP543-2022-190.

Tikoff, B., and Shipley, T.F., 2025, Mt Stuart, Washington State: Beware Ockham's razor: GSA Today, v. 35, no. 5, p. 4–9, https://doi.org/10.1130/GSATG108GM.1.

Wegener, A., 1915, The Origin of Continents and Oceans (Die Entstehung der Kontinente und Ozeane): Braunschweig, Germany, Friedr. Vieweg & Sohn, 94 p.

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