GLOBAL LAND OUTLOOK WORKING PAPER

"SO THE LAND IS ACTUALLY LIKE A BIG BOOK, YOU KNOW?"

Geomythology, and the value of a bridge between conventional and indigenous science

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September 2017

United Nations
Convention to Combat Desertification

CONTENTS

1. INTRODUCTION

The words of Alison Anderson, Papunya elder and recently retired Australian politician, resonate (Miller, 2007). They resonate with all indigenous peoples whose relationship with their land is often more profoundly intimate than that of Western or eurocentric societies, and they resonate with a geologist. For Aboriginal people and geologists, the land tells stories – in different ways, of course, but the land is itself is viewed as a book whose narratives must be not only deciphered, but recounted. Anderson's view echoes that of John Wesley Powell, the extraordinary one-armed geologist, explorer, and cultural anthropologist, as he variously hurtled, drifted or clambered down the Grand Canyon in his epic expedition of 1869. In his diary and report he recorded that "All about me are interesting geologic records. The book is open and I can read as I run" (Powell, 1875). His report included a graphic and dramatic image of this 'book' (Fig. 1).

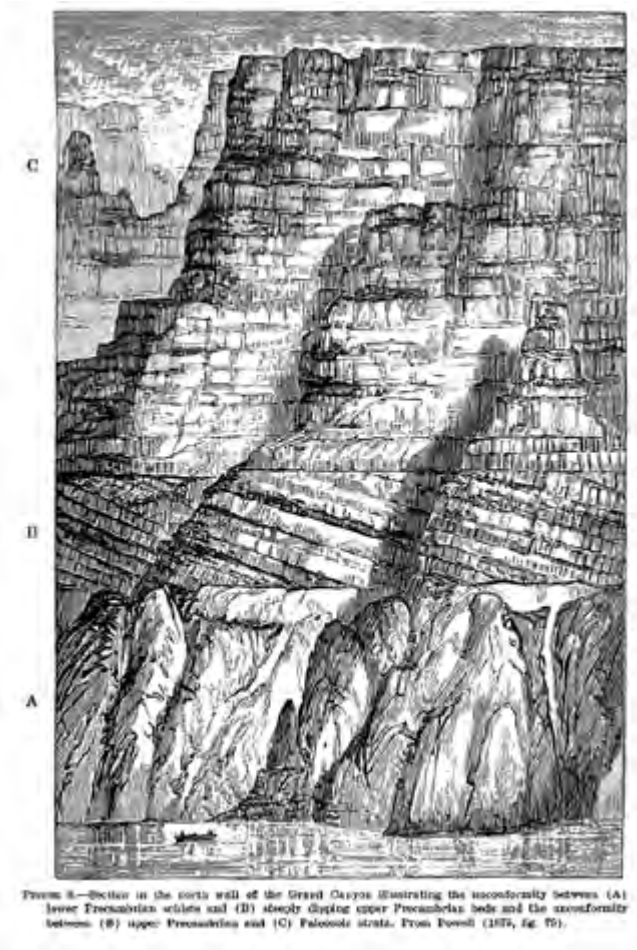


Figure 1: John Wesley Powell's "book."
Source: U.S. Geological Survey

It is evident that Powell shared, to a far greater extent than was typical of those times, the ways in which the land was perceived by the Native Americans of the region – whose company he cultivated, and whose culture fascinated him. Despite his strong emotional connection to the land, as a scientist, he valued the arid lands of the American West in a far more rational way than most of his fellow citizens (and certainly politicians), who spoke only in terms of conquest and "manifest destiny." In understanding the limitations for development of those arid lands, he was remarkably prescient. More than 120 years ago, he declared, to a booing audience of vested irrigation interests, "I tell you, gentlemen, you are piling up a heritage of conflict and litigation over water rights, for there is not sufficient water to supply these arid lands" (Los Angeles Chamber of Commerce, 1893). He was, tragically, ignored.

Powell's vision of how to read the land and how to understand it – never mind manage it – was not far removed from that of its indigenous inhabitants. His ideas were embedded in the science of the day, but went far beyond it into a deep awareness of the relationships between the land and its inhabitants, and a romantic perception of that land. While describing the canyonlands of the Colorado as "the land of music" with landforms sculpted by "tempests through ages too long for man to compute," he confessed that "The wonders of the Grand Canyon cannot be adequately represented in symbols of speech, nor by speech itself. The resources of the graphic art are taxed beyond their powers. Language and illustration combined must fail" (Powell, 1895). Powell was ahead his time in appreciating the cultural value of this land, and in defiance of the cultural norms of his time by falling under its spell and perceiving what can only be described as its spiritual value.

Today, Powell's science and his reading of the 'book' remain, quite correctly, much admired, and the lyricism of much of his perception of the landscape, together with his romantic viewpoint, readily accepted. Powell observed that "The Indians, too, have woven the mysteries of the canyons into the myths of their religion" (Powell, 1895). He relished those stories, being wishful of developing a relationship of mutual respect with the Native American peoples of the region, and of understanding how they themselves perceived and interpreted the open book of their land. Yet today, the Western or eurocentric mindset dismisses, or at best categorizes, the stories of indigenous people worldwide as exactly that – myth.

Figure 2: **Kata Tjuta.**

This, despite one of the stories of the Havasupai, long residents of the Grand Canyon region, describing the waters of the Colorado River cutting down through the rocks on their way to the sea. This, despite clear evidence that Australian Aboriginal stories record real geological, landscape-shaping events embedded in the genuine mythology of the Dreaming, or that the old Navajo place name for the Dilophosaurus dinosaur trackway near Cameron, Arizona, is "Place with Bird Tracks" (Mayor, 2007).

The eurocentric worldview requires science to be firmly separated from folklore, insists on science being endlessly partitioned into sub-disciplines, takes for granted that the living world must be distinct from the non-living, and regards a holistic view of the world as being purely philosophical, religious, and non-valid. If we are to contemplate the cultural and spiritual values of the land, then these assumptions need to be examined, the common human need to make sense of the world around us, celebrated, and cultural bridges built.

Figure 3: **Streaks of desert varnish or Wanambi's beard?**

2. GEOMYTHOLOGY

The spectacular landscape shown in Figure 2 is in the central Australian desert, not far from Uluru. The thirty-six dramatic and ruggedly rounded rock hills were originally named, in the grand tradition of Western colonial patronage, "The Olgas," after a Queen of Württemberg. For the local Pitjantjatjara people, they are, more descriptively, "Kata Tjuta" or "many heads", and they are sacred land. For a geologist, the dark stains streaking down the flanks (Figure 3) are desert varnish, an enigmatic rock coating typical of all arid areas, part mineral, part microbial. For the Pitjantjatjara and the Anangu Aboriginal cultures, these stains are the hairs of the long beard of Wanambi (or Wonambi), the great snake king who lives on the highest summit and only descends, using the caves, during the dry season. For a geologist, the rock domes tell a story that begins more than 500 million years ago, a story of pebbles, gravel, and sand flushed down into an ancient sea, buried, solidified, tilted, uplifted, eroded. For the Aboriginal people, each summit represents – indeed, is believed to be – a being from the Dreamtime. Some of the domes are identified with the Ancestors, known as mice women, and individual rocks, the food prepared for them. Then there is Malu, a dying kangaroo man who leans on a rock that is his sister, the lizard woman Mulumura, who comforts him. The stone bodies of the Pungalunga, giant cannibals, are also there, and the winds of Wanambi's breath blow through the gorges. But the details of the stories and the ceremonies that take place at Kata Tjuta are sacred secrets, which makes the work of the geologist wishful of understanding them all the more challenging.

In 1966, Dorothy Vitaliano, a US Geological Survey geologist, coined the term "geomythology" as a result of her interest in the relationships between the legends of Atlantis and geological evidence. In 1973, she developed her ideas into the ground-breaking book *Legends of the Earth: Their Geologic Origins* (Vitaliano,1974); in the preface, she wrote of her "hope that in its own small way such a book might help bridge the gap between the scientist and the nonscientist."

The book was global in scope, not only documenting stories and correlating them with associated geologic features and phenomena, but setting out the framework for a valid new discipline. Dividing geologically inspired folklore into stories satisfying the human need for explanation (etiological), and those originating from the witnessing of real events (euhemeristic), she commented that the sub-discipline of geomythology

> … involves geology, history, archeology and folklore – in other words, the natural sciences, social sciences, and humanities. Thus geomythology is undoubtedly the most interdisciplinary geoscience of them all.

Vitaliano's concept of geomythology stimulated some interest, but for many years remained marginal and was regarded – since it contemplated explanations that were clearly scientifically unconventional and thus "false" – as hardly a subject for serious research. However, this changed in 2004, when the 32nd International Geological Congress held a session, entitled "Myth and Geology", of which Vitaliano was the keynote speaker. This new sub-discipline of geoscience was, thereby, finally given credibility and academic gravitas, cemented by the subsequent publication of the (peer-reviewed) papers from the session as a Special Publication of the Geological Society of London, in 2007 (Piccardi & Masse, 2007).

In the preface to that volume, one of the editors, an Italian geologist, Luigi Piccardi, wrote,

> The interpretation of geological folklore, to be correctly and exhaustively carried out, requires the integration of knowledge in the fields of geology, archaeology, history, comparative mythology and anthropology. The geological study of mythology and legendary accounts may reveal encoded memories of past geological events, thus providing a reservoir of geological information. On the other hand, it also helps to provide new insight to historical, archaeological and anthropological research, opening a new window on a field traditionally reserved for anthropologists, and improving the 'self knowledge' of Man, by shedding new light on his early perception of the world. 'Know thyself' was the motto inscribed on the temple of the most famous sanctuary of antiquity, the Oracle of Apollo at Delphi. The myth at the origin of this Oracle has recently been the subject of one of the best case histories in geomythology.
>
> In addition to outlining the relationship between myth and geology, this volume will inspire its readers to look deeper into the roots of culture and our perception of the natural environment, through various case histories of myths, legends, folk tales and oral traditions from around the world. (Piccardi, 2007).

A classic example of stories that explain features of the land (and one of Vitaliano's favorites) is that of the Devil's Tower in Wyoming, declared the country's first National Monument by Theodore Roosevelt, in 1906. A geologist sees this imposing landform (Figure 4) as the erosional remnant of a body of molten magma, forced up into the earth's crust around 50 million years ago, and stubbornly resisting subsequent erosion of all the originally surrounding rock. The characteristic columns – the same phenomenon of columnar jointing seen in the geomythological sites of Ireland's Giant's Causeway, and Scotland's Fingal's Cave – result from the physics of cooling magma.

Native Americans of the plains – Arapaho, Crow, Lakota, Cheyenne, Kiowa, Shoshone – have, for countless generations, seen the Devil's Tower as a place of deep spiritual and cultural significance. Their stories, while differing in detail, all resonate with a common theme: a bear. Native American names for the tower include "bear's lodge" and "bear's tipi." The stories tell of a group of people being pursued by a giant bear, appealing to the gods for help, and being rescued by the ground beneath their feet, uplifting them beyond the bear's reach. The story further details how the columns were caused by the bear's claw marks as it desperately scratched the rock.

Figure 4: **Devil's Tower.**
Source: Wikipedia, public domain

Figure 5: **The myth of the "bear's lodge." Source: U.S. National Park Service**

The myth is illustrated in Figure 5, from the painting hanging in the National Monument's visitor center.

Etiological stories of the land abound in every indigenous culture across the globe and comprise the fabric of spiritual belief. For Australian Aboriginal peoples (in common with so many indigenous cultures) the land, "country" – Alison Pearson's "big book" – is, and means, everything. They are part of the land and the land is part of them; it is their larder, pharrmacy, hardware store, and place of worship. Virtually every feature – be it a hill, sand dune, or boulder – has a story, an origin, in the Dreamtime and the creation journeys and adventures of the ancestors, human or otherwise. In her book, *Nourishing Terrains: Australian Aboriginal Views of Landscape and Wilderness* (Rose, 1996), Deborah Bird Rose described how Dorothy Tunbridge, in collecting stories of the Adnyamathanha people, in the Flinders Ranges of South Australia, formed an understanding of the intimate links between Dreaming, land, and law:

> … the Dreaming signifies two things above all, the land and the law … For the people, the stories are the land. In the language Yura Ngawarla, 'telling (someone) a story', *yarta wandatha*, means simply 'telling (someone) the land (*yarta*)' or 'linking (that someone) to the land'.

Additionally, "the law", for Aboriginal people, is itself the land:

> In many parts of Australia, the ultimate origin of the life of country is the earth itself, as Hobbles Danaiyarri, a Mudbura man of Yarralin (Northern Territory), explained: "Everything come up out of ground – language, people, emu, kangaroo, grass. That's Law."

The resulting canon of stories is vast, diverse – and compelling. For an open-minded geologist, they work, not in conflict with the science but in parallel, as complementary perceptions of the same landscape: both desert varnish and Wanambi's beard. Outcrops of yellow ochre can be hydrated iron oxide, or ancestral faeces. A bizarre terrain of huge rounded boulders ("Devil's Marbles" according to colonial nomenclature) can form from the spheroidal weathering of ancient granite, or from clumps of hair dropped on the ground by a giant human ancestor. Green pebbles can be the river-worn detritus of ancient metamorphic rocks, or simply the result of ancestral emus suffering from diarrhoea. Columnar jointing can reflect the physics of cooling magma, or the claw marks of a frustrated giant bear.

All such stories are evocative and spiritually important, but it is now recognized that deep cultural memories contain knowledge of factual and true geological events – Vitaliano's "euhemeristic" geomythology. All the archaeological evidence points to Australia's initial settlement having occurred more than 50,000 years ago – as such, one may assume that 1,700 generations of collective memory have been preserved in some form through oral narratives. For indigenous peoples, whether Navajo or Papunya, there is no distinction between personal identity and place; moreover, place is the land, and the land itself has memory. Unlike eurocentric cultures and religions, indigenous peoples often believe that human origins lie beneath the surface of the earth, creating a spiritual intimacy with the workings of the planet. For Native Americans of the Grand Canyon region, their place of emergence, *sipapu*, lies within the canyon. For many of them, their world is explicitly three-dimensional, with six cardinal directions (the four conventional plus above and below). Places that potentially provide subterranean access – canyons, craters, caves, fissures, springs – have, for the entire history of our species, held great spiritual significance. The concentration of rock art in such places, worldwide, over the last 40,000 years, bears witness to this. This form of art documents changes in climate, extinctions, floods, and geological unrest.

Events that reshape the landscape feature prominently in geomythological narratives: earthquakes, volcanic eruptions, meteorite impacts, floods and tsunamis are among the most dramatic.

At some point in the second half of the eleventh century, volcanic eruptions rapidly changed the landscape of southeastern Arizona. The cone of Sunset Crater (Figure 6) rapidly built up to a height of 340 meters, expelled lava flows, engulfing the surrounding land, and spewed ash over 2000 square kilometers, devastating local communities (US National Park Service, 2005).

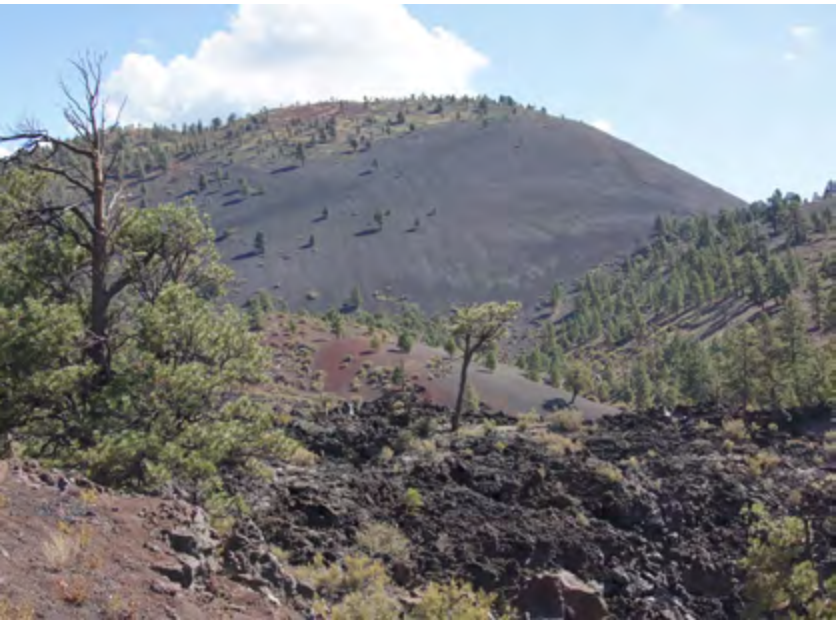


Figure 6: **The volcanic cone of Sunset Crater.**

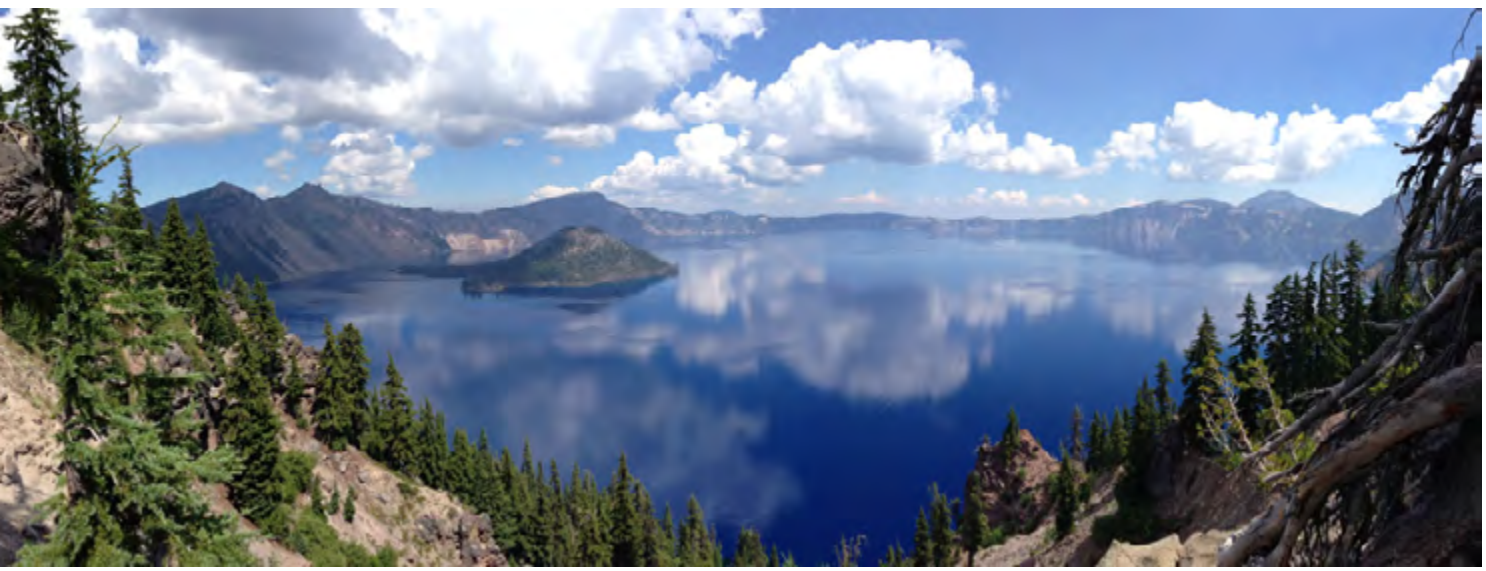
Western Pueblo cultures revere *katsinas* (or *kachinas*), powerful spirits who embody ancestors, all natural forces, historical events, and moral principles.

Hopi stories of their ancestors living around Sunset Crater recount how Ka'nas katsina became angered with the behavior of a group of evil young men in the local village and started the eruption as punishment, but stopped it before the village was destroyed. Drought and famine inevitably followed the blanketing of the land in ash, but once rid of the evil members of society, Ka'nas katsina took pity on the people and provided them with magically multiplying ears of baked corn. The eruption caused a migration of the modest population, in all probability to the nearby Wupatki pueblo, where, ironically, the soil from the volcanic ash weathered to provide fertile soil, and the community flourished. Intriguingly, corn is a vital feature of Hopi beliefs and ceremonies and Ka'nas katsina wore strings of baked corn as body decoration. Not long ago, fifty-five pieces of lava were found at a habitation site near Sunset Crater that bore the clear imprints of husked corn (Elson, Ort, Hesse, & Duffield, 2002). It seems likely that the corn cobs were placed in the path of the advancing lava as a ritual offering, the rocks being later retrieved and carried home as sacred objects.

The spectacular Crater Lake in Oregon (Figure 7) was created 7,600 years ago by the catastrophic explosive eruption and collapse of Mount Mazama, an event that is recorded in the legends of local Native Americans.

The chief of the Below World, seated atop Mount Mazama, was spurned in love and swore that he would wreak fiery destruction on the land. The chief of the Above World, residing on the Californian volcano of Mount Shasta, swore to prevent this and the two entered into a titanic battle in which huge red-hot boulders were flung through the sky and burning ash fell on the land, spreading darkness.

Figure 7: **Crater Lake.**
Source: Creative Commons Attribution-Share Alike license.
Author: Epmatsw



The chief of the Below World flung so much fire and rock into the sky that the mountain collapsed beneath him and flung him back to the underworld. The resulting hole (the volcanic caldera) then filled with water to form Crater Lake. The legend serves as a fine description of a gigantic volcanic eruption and caldera collapse (McWilliams, n.d.).

Craters formed from meteorite impacts also, understandably, feature heavily in geomythology. South of Sunset Crater lies Meteor Crater, a beautifully preserved impact feature from around 50,000 years ago – long before humans settled in the area, yet the Hopi have a story for it involving a fiery star falling from the sky as punishment for people who had offended the spirits. Not far south of Alice Springs in the Australian outback lies the Henbury Crater Field (although for the local Arrernte people it is named *Tatyeye Kepmwere* (its meaning sacred) rather than the name of a nearby cattle station). Less than five thousand years ago, a meteorite disintegrated and crashed to Earth, leaving thirteen modest-sized craters over an area of just 1.25 square kilometers (Hamacher & Norris, 2009; Hamacher & Goldsmith, 2013). The site is sacred to local Aboriginal people but essentially forbidden to them since a fire-devil is believed to live there, having fallen from the sky bringing punishment and death: "A fiery devil ran down from the Sun and made his home in the Earth. He will burn and eat any bad blackfellows ..." An alternative to this story is that the largest crater, and the debris scattered around it, were caused by the lizard woman Mulumura (she of Kata Tjuta) scooping up handfuls of soil and tossing them out of the hole in which she was camping (Hamacher & Goldsmith, 2013). The *tektites* found scattered across the Australian desert – small globular glassy pebbles generally regarded as originating from molten material thrown out of an impact crater – might then, following the story, be the work of Mulumura. Aboriginal people collect these pebbles (and occasionally sell them) as powerful and mysterious sacred objects.

The story of the falling fire-devil at *Tatyeye Kepmwere* potentially correlates with a meteorite impact event witnessed by humans, who then passed down the story over a few hundred generations; there are, inevitably, uncertainties surrounding the legend. It is within the bounds of possibility, although by no means certain, that these stories may be colored by the geological interpretations of the colonists to whom they were told. The evidence is mixed, further complicated by the stories and their details being protected by cultural secrecy. However, these uncertainties may, in fact, be of little relevance, given that these stories represent an informative and creative interweaving of scientific and spiritual knowledge.

Far to the northwest of *Tatyeye Kepmwere* lies the huge Wolfe Creek Crater, notorious for two dubious horror films, and as the largest impact crater in Australia, second only worldwide in preservation to Meteor Crater, in the US (Hamacher & Goldsmith, 2013). Akin to its colleague in Arizona, it was formed roughly 300,000 years ago, long before humans settled in the area, but geomythological stories about its formation abound. The most common is that it is the place where Kalpurtu, a great Rainbow serpent, surfaced, after his long subterranean journey. It is also described as the deep hole where the evening star fell to Earth, accompanied by a brilliant explosion and a deafening roar. The star story suffers from the same uncertainty as that of the fire-devil, at *Tatyeye Kepmwere,* along with the possibility of having been influenced by colonial writers, geologists, and anthropologists.

The geomythology of extraterrestrial impacts and volcanism abounds in indigenous cultures across the world, but the planet's repertoire of land-sculpting processes is by no means limited to such catastrophes. Given that humans have been roaming the Earth since long before the last glacial maximum, it is hardly surprising that they have recounted stories of sea-level change, glacial floods, and dramatic shifts in climate – stories that contain real information, of value to what might be termed "conventional," eurocentric science. As the glaciers retreated from the northwestern US and Canada, around 12,000 years ago, the effects on the landscape were radical. Ice dams and glacial debris blocked valleys and rivers, while huge lakes built up behind these dams – Glacial Lake Missoula reached an extent of 7,700 square kilometers. When then the dams subsequently burst, vast volumes of water hurtled hundreds of kilometers to the sea, at a speed sixty times that of the flow of the Amazon River, scouring and carving an entirely new landscape – the so-called Channeled Scablands (US Geological Survey, 1976). Nor was this a singular event: as the geological drama of retreating and periodically re-advancing glaciers over hundreds of thousands of years played out, repeated floods scoured the land. Although this interpretation of the formation of these unique landscapes was originally proposed in the 1920s, it was long regarded as outrageous, geological heresy, a return to the derided biblical "catastrophism" of the nineteenth century. The emotional academic debate was only settled in the 1970s – but the indigenous peoples had long known of these events.

In the publication, entitled "Indigenous Knowledge and Geoscience on the Flathead Indian Reservation, Northwest Montana: Implications for Place-Based and Culturally Congruent Education" Johnson et al. (2014) documented, in compelling geological and geomythological detail, the evolution of one particular glacial landscape "through the integration of geoscience, traditional tribal knowledge, and oral narratives" (Johnson et al., 2014). The potential importance of such work, applicable worldwide, is summarized in a section entitled "Similarities between indigenous narratives and geologic interpretations of the landscape":

> Indigenous narratives originating in western Montana … are consistent with massive local landscape transformations due to movements of great ice sheets and the erosive powers of glacial meltwaters. Hydrologic processes play critical roles in both the geoscientific and the traditional indigenous narratives regarding the formation of the Big Draw Valley on the Flathead Indian Reservation, and the traditional stories and Western geoscience theories exhibit intriguing similarities with regard to the content and timing of major events. Local indigenous knowledge may prompt a reconsideration of current geoscience theories regarding the glacial history of the valley.

Today, flooding in the Red Centre of Australia is rare (yet, when it occurs, is often devastating), but this has not always been so. The Australian colonists, perhaps unwilling to believe that the divine plan for their continent could be so insulting as to leave the interior entirely barren, told stories (Maslen, 1836) of a great inland sea, "The Delta of Australia," and "The Great River of the Desired Blessing." They were, as exploration would finally, incredibly, confirm, rather too late in their arrival – the lakes, as they had envisaged them, were already dry, as the Aboriginal People knew very well. Today, in the midst of what colonial culture referred to as "The Ghastly Blank," lies Lake Eyre (now renamed Kati Thanda–Lake Eyre), a vast basin covering 15% of the continent, lying up to fifteen meters below sea level. It is, for most of the year, an expanse of salt pans with dozens of small salt lakes that expand during the rainy season. Every few years, significant floods "fill" the lake, the most notable flood of recent times occurred in 1974, covering the basin in six meters of water (Habeck-Fardy & Nanson, 2014). But even in such times of generous floods, the Kati Thanda–Lake Eyre is a mere shadow of its former self. The climate of Australia has been changing for hundreds of millions of years, but of particular interest are the ways in which it responded to global fluctuations of aridity during the Ice Ages. A hundred thousand years ago, conditions were much wetter than today, vegetation and wildlife flourished, and today's Kati Thanda–Lake Eyre would have been invisible beneath the waters of a vast "mega-lake" covering more than 30,000 square kilometers. The lake then receded, refilling again significantly 65, 50, and 30,000 years ago; less dramatic expansions occurred several times thereafter (Habeck-Fardy & Nanson, 2014; Cohen et al., 2011).

In 1901, John Gregory, a British geologist, explored the Lake Eyre region and later published a description of his journey, rather depressingly entitled *The Dead Heart of Australia* (Gregory, 1906).

> According to the traditions of some Australian aborigines, the deserts of Central Australia were once fertile, well-watered plains.
>
> Instead of the present brazen sky, the heavens were covered by a vault of clouds, so dense that it appeared solid; where to-day the only vegetation is a thin scrub, there were once giant gum-trees, which formed pillars to support the sky; the air, now laden with blinding, salt-coated dust, was washed by soft, cooling rains, and the present deserts around Lake Eyre were one continuous garden. The rich soil of the country, watered by abundant rain, supported a luxuriant vegetation, which spread from the lake-shores and the river-banks far out across the plains. The trunks of lofty gumtrees rose through the dense undergrowth, and upheld a canopy of vegetation, that protected the country beneath from the direct rays of the sun. In this roof of vegetation dwelt the strange monsters known as the "Kadimakara" or "Kadimerkera."
>
> … This legend is part of the folk-lore of the Dieri, a tribe found in the country along Cooper's Creek, eastward from Lake Eyre. The same legend is told by other tribes in the same district of Central Australia, with variations in the form of the names, and in other details. It may have arisen as a pure fiction, invented by some imaginative, story-telling native, to explain why large bones are scattered over the bed of Cooper's Creek. It may, on the other hand, be a shadowy reminiscence of the geographical conditions which existed in some distant ancestral home of the aborigines, or of those which prevailed in Central Australia, at some remote period. What geographical conditions, it may be asked, could have given rise to such a legend?

Those "geographical conditions" which gave rise to such a legend are, in fact, now known. Firstly, to detail the legend, the name Kati Thanda was the sacred name for the Arabana people, meaning "the name of the lake which was formed after the skin of a kangaroo was spread over the ground." The kangaroo ancestor had made a long journey and the story describes how it experienced different flora and fauna until it was unfortunately killed and skinned by an Arabana man, and the lake was created. The region of the lake is rich in flora and fauna and becomes dramatically so after the rains, but this diversity is nothing compared to the days when, as recounted to John Gregory, "the present deserts around Lake Eyre were one continuous garden" and the Kadimakara dwelt there. The Aranda stories of the Kadimakara are but samples of similar Dreamtime narratives from across Australia, tales of giant creatures that roamed the lush landscape until aridity came and they finally perished in the desiccated marshes of Kati Thanda–Lake Eyre. During subsequent times of drought the local people would use the bones of the Kadimakara in ceremonies appealing for rain. These stories document the times of the Australian mega-fauna whose remains and diversity have been proven beyond doubt (Wroe et al., 2013; Prideaux et al., 2010).

Wetter conditions than today allowed huge and unique terrestrial vertebrates to roam the outback until disappearing almost completely, around 40,000 years ago, at which point Australia lost more than 90% of these large vertebrates in what amounted to a mass extinction. The debate still rages as to whether climate change or hunting (or a fatal combination of both) was the cause, but there could be no clearer case for indigenous narratives originating from, and echoing that which, is otherwise referred to as scientific truth.

Among the gigantic reptiles, marsupials, flightless birds, and ducks was *Wonambi naracoortensis,* a snake that grew up to six meters in length, and killed its prey by constriction. It was the last in a line of a group of giant snakes found on other continents of the old supercontinent Gondwana, but which died out around 55 million years ago – except in Australia where they diversified and thrived (Prideaux et al., 2010). As such, it is small wonder that giant serpents, Rainbow Snakes, are at the heart of Australian spiritual beliefs and are still present in the legends of Kata Tjuta.

The narratives of geomythology can be informative, stimulating, and evocative, but it is becoming increasingly recognized today that their value reaches far beyond this, and that there are wide-ranging contexts in which that value can be explored, cultivated, and applied.

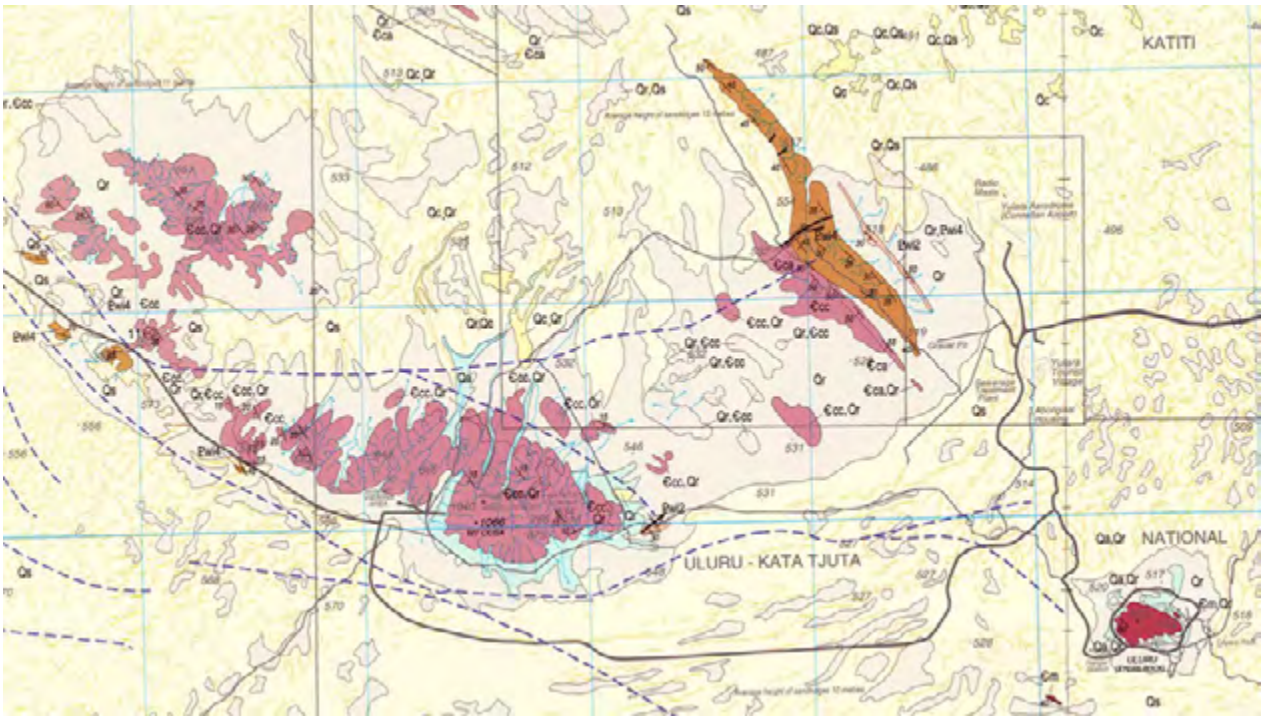
3. READING THE LAND, BUILDING BRIDGES

While much of the science which takes place today occurs in a laboratory, and in front of a workstation, the roots of the geologist's trade lie in fieldwork, and it is the joys of exploration and the challenges of reading the land that bring many to the profession. The geological map is the essential element when it comes to reading the land; it is the interpretation, a colorful documentation of the fabric and history of the landscape. Part of the Australian government's geological map showing Kata Tjuta and Uluru is shown in Figure 8 – a map that tells stories probably recognizable to the Pitjantjatjara people.

Geologists both draw the maps and, invariably, carry the appropriate ones along, during their fieldwork. However, it is not uncommon for a geologist to reach the point of discarding the map, sitting down and simply immersing himself in the landscape, its beauty and its stories, geological, cultural, and spiritual. It becomes abundantly clear, at such a point, that all of those stories are embedded in the land and that they are absolutely not mutually exclusive, simply different, overlapping cultural perceptions of exactly the same features from differing worldviews.

Innate value can be gained from delving into and analyzing all these stories in parallel, building bridges between the worldviews they represent. The International Geological Congress session on "Myth and Geology", and the subsequent Geological Society publication were ground-breaking in bringing such ideas into a respectable scientific realm.

Figure 8: **The geological map of Kata Tjuta and Uluru. Source: Australian Geoscience Information Network**



In a typically cross-disciplinary paper entitled "Exploring the nature of myth and its role in science", Masse, Barber, Piccardi, and Barber (2007), of New Mexico's Los Alamos National Laboratory, remarked that

> Like the proverbial tip of the iceberg, much useful natural history information is undoubtedly lurking in the large body of as yet unanalysed world myths. Such study should complement and add to our understanding of Earth process and Earth history. At the very least, our various geomythology researches provide us with a profound respect and appreciation for the observational powers of our ancestors, and help to demystify the mythological past.

The potential power of these ideas extends far beyond the geosciences, most importantly into the realms of education, public awareness, planning and sustainability. In the abstract for their paper, from the same publication, "From myth to Earth education and science communication," Lanza and Negrete (2007) noted that

> There is a longstanding and intimate relationship between myths and the Earth. Myths represent human beings in childhood when a primitive language made of symbols transmitted the wisdom necessary to live in harmony with nature. Today science uses mainly the language of data. Nevertheless, myths and legends are still popular and part of our culture, and the Earth sciences remain confined mostly to the world of scientists. This paper is an attempt, from the perspective of science communication, to provide a theory that uses myths and legends to stimulate the curiosity of the man in the street about the planet we live on. Recent studies have demonstrated that fictional stories can be used to convey science to the general public in an accurate, memorable and enjoyable way. Following these ideas, we believe that myths can be a useful tool for Earth science studies, learning and popularization.

And they concluded:

> Some studies encourage us to believe that scientific discoveries cannot replace myths and legends. Their symbolic language still constitutes a common human heritage that, other than being relegated to superstition, can add value to our interpretation of reality. Early human civilizations used myths to organize and convey information for transmitting the wisdom necessary to live in harmony with and survive in nature. Since myths are a type of narrative, they have a structure familiar to most people. Today the narrative mode is considered to be a reliable way to express and transmit information, complementary to paradigmatic cognition. Thus, it is possible to consider myths as charming tales and useful tools capable of representing information, creating meaning and enriching the knowledge developed by Earth scientists about the planet.

Science – neither more nor less than the myths of indigenous peoples – is underpinned by a cultural perspective. It represents a cultural practice and system, a worldview that is founded on analytical detachment, and which follows the concepts of Cartesian dualism, the separation of mind and matter, of man and nature, of the living and the non-living. By its own definition, scientific knowledge separates itself from other kinds of knowledge that do not fall within its own rationale for "truth." In doing so, it erects barriers to comprehension and hierarchies of expertise and perceived validity. In this context, the knowledge of indigenous peoples is easily stereotyped and dismissed as false or fictional, not least because it originates in oral cultures, which have long been disdained by eurocentric science and philosophy. Yet vast depths of human experience lie in the narratives of these cultures. If these barriers are to be broken down, and value extracted from so doing, it is worth contemplating how such a goal may be achieved.

This goal is increasingly being seen as intellectually valid and cross-disciplinary research and experiments have gathered pace – most noticeably in Canada, Australia, and the US. The most notable, comprehensive, and compelling summary of such work, and related issues and methodologies, is the book *Bridging Cultures: Indigenous and Scientific Ways of Knowing Nature* (Aikenhead & Michell, 2011). Written by the Canadian pioneers in this field, Glen Aikenhead and Herman Michell, this book should be required reading for anyone determined to exploit the potential of shared worldviews. In the opening sections, they wrote that

> The recognition of Indigenous knowledge as an important and legitimate source of understanding of the physical world is increasing within education jurisdictions worldwide. Consequently, this content appears, or is beginning to appear, in science curricula… To build cultural bridges between Indigenous and scientific ways of knowing nature, one first needs a contemporary and general understanding of each knowledge system.

Aikenhead and Michell further pointed out that

> Empirical research shows that a majority of students prefers to understand nature through other worldviews… On a personal level, they do not relate easily to a scientific worldview and they often experience school science as a foreign culture. Science-shy students become uninterested and can be frustrated or even alienated by their experiences. Their intuitive or subconscious reaction may be so subtle that science teachers seldom detect it.

It must be emphasized that, as educators, the authors focus on the application of bridging cultures to formal education contexts (importantly, for both indigenous and non-indigenous students). But the applicability of their ideas reaches far into the wider world of society as a whole and science communication – an appreciation and understanding of Kata Tjuta is surely enhanced by both the science of desert varnish and the stories of Wanambi.

Aikenhead and Michell compellingly set about dismantling the notion of eurocentric science versus indigenous knowledge through examining the tenets of both, their similarities and contrasts. Perhaps the most striking contrast is the essentially universal indigenous view of the world as intrinsically holistic. There is no separation between man and nature, between the living and the non-living, between personal identity and the land, the place. This is, of course, hardly the viewpoint of conventional science – and yet there are ways in which this distinction becomes blurred. Science is driven by the conviction that the world and the universe are ultimately knowable and yet the renowned theoretical physicist, Werner Heisenberg, wrote (Heisenberg, 1959) that

> … we have to remember that what we observe is not nature in itself but nature exposed to our method of questioning. Our scientific work in physics consists in asking questions about nature in the language that we possess and trying to get an answer from experiment by the means that are at our disposal. In this way quantum theory reminds us, as Bohr has put it, of the old wisdom that when searching for harmony in life one must never forget that in the drama of existence we are ourselves both players and spectators.

And that "Natural science does not simply describe and explain nature; it is part of the interplay between nature and ourselves." Heisenberg described as an illusion the idea that science could describe the world without any reference to *us.* He was one of the pioneers of quantum theory, which he said "provides us with a striking illustration of the fact that we can fully understand a connection though we can only speak of it in images and parables." Quantum physics, together with that of black holes, relativity, dark matter, the multiverse, and string theory, flies in the face of classical science and throws into question the role of ourselves as detached observers. The prominent Stanford University theoretical physicist Leonard Susskind went so far as to exhort scientists to "get rid of the word 'reality'" and described the actual process of science as being "as human and as chaotic and as contentious as anything else" (Susskind, 2011).

Another of the twentieth century's prominent theoretical physicists, David Bohm, developed an entire ultra-holistic cosmic philosophy in his book *Wholeness and the Implicate Order* (Bohm,1980), in which he described the "unbroken wholeness of the totality of existence as an undivided flowing movement without borders." Bohm, in considering that "unbroken wholeness" constantly referred to the need for "harmony," thus echoing another of the fundamentals of indigenous spiritual beliefs, worldwide.

Furthermore, the Earth sciences themselves are not beyond holistic thinking. Much of the creativity of geoscience today is focused on Earth System Science, the approach whereby geologists, geophysicists, geochemists, sedimentologists, palaeontologists, geomorphologists, climatologists, stratigraphers, isotope analysts, archaeologists, biologists, botanists, bacteriologists, sociologists, anthropologists, historians, and philosophers join together in the common quest to properly comprehend the connectedness, on an immense range of scales, of their individual disciplines. These tribes have not yet settled their differences, but every day brings startling results that restructure the comfort of conventional wisdom. Even the familiar separation of the organic from the inorganic, the living from the non-living, begins to break down. Minerals, for instance, although they are theoretically dead, have undergone a process of what is best described as evolution, which is traditionally associated only with living things (Hazen, Grew, Downs, Golden, & Hystad, 2015). Since our planet's beginnings, the diversity of minerals, their relative abundance, and their chemistry and physical characteristics have changed dramatically, and most of these changes have been intimately entwined with the evolution of life. One provocative question that emerges from multidisciplinary grouping of experts and challenges conventional categorization regards when and how biochemistry evolved from geochemistry. Entire Earth science introductory textbooks are structured around a systems approach to the otherwise compartmentalized sub-disciplines (Christiansen & Hamblin, 2015).

Taken to an extreme, the concepts of the Earth system lead to the controversial Gaia hypothesis, proposed by James Lovelock in the 1960s, and to viewing our planet as a self-regulating system, living and non-living components comprising parts of a single organism (Lovelock, 1972; New Scientist, 2013). These ideas come in a spectrum of formulations, from "strong" to "weak," and while they remain on the fringes of mainstream science, some of their concepts nevertheless overlap with the continuous developments of humanity's appreciation of intimate biosphere/atmosphere/lithosphere interactions. While these views – including the concept of natural equilibrium and harmony – are perhaps best engaged with as metaphors, they are too easily dismissed by conventional eurocentric science, and they clearly resonate with the spiritual beliefs of indigenous peoples, worldwide.

Conventional eurocentric science (together with philosophy, religion, and the history of colonial politics) is founded on the basic assumption of the superiority of *Homo sapiens* over all other forms of life, and over nature as a whole. Humanity is viewed as somehow outside nature, whose resources exist to be exploited; in other words, humanity is believed to hold dominion over nature, lands existing merely to be conquered, while the 'ghastly blanks' appear as needing to be tamed, following mankind's 'manifest destiny.' This worldview is the diametric opposite of that of indigenous peoples, who regard themselves as participants in nature, and for whom the land is a living entity, to be cherished and respected. Eurocentric science is, however, constantly evolving and today there are ways in which these apparently conflicting worldviews can be, at least to some extent, reconciled. In his classic work, *A Sand County Almanac* (Leopold, 1949), Aldo Leopold raised the concept of a "land ethic" which "simply enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land". Leopold further detailed:

> A land ethic of course cannot prevent the alteration, management, and use of these 'resources,' but it does affirm their right to continued existence, and, at least in spots, their continued existence in a natural state. In short, a land ethic changes the role of Homo sapiens from conqueror of the land community to plain member and citizen of it. It implies respect for his fellow-members, and also respect for the community as such. In human history, we have learned (I hope) that the conqueror role is eventually self-defeating. Why? Because it is implicit in such a role that the conqueror knows, *ex cathedra*, just what makes the community clock tick, and just what and who is valuable, and what and who is worthless, in community life. It always turns out that he knows neither, and this is why his conquests eventually defeat themselves.

With today's emphasis on sustainability, on comprehension and management of the environment, and on understanding the complexities of ecosystems, thinking has evolved (admittedly in areas that remain on the fringe of the mainstream) into a wide range of concepts that challenge the conventional anthropocentric wisdom of the divisions and relationships between man and nature. For example, the philosophy of "Deep Ecology," clearly influenced by the Gaia hypothesis, describes itself as a "movement": "Adherents of the deep ecology movement share a dislike of the human-centered value system at the core of European and North American industrial culture. Deep ecologists argue that environmental philosophy must recognize the values that inhere objectively in nature independently of human wants, needs or desires." (Callicott & Frodeman, 2009).

The areas of consonance between the seemingly conflicting worldviews of conventional science, eurocentric philosophy, and indigenous knowledge are far broader than might be instinctively apparent, and are carefully examined (along with the contrasts) by Aikenhead and Michell (2011), who pointed to "the shared intellectual processes such as observing, questioning, interpreting, looking for patterns, inferring, classifying, predicting, verifying, problem solving, adapting, monitoring, and so on." Although rooted in distinct cultures, there are robust cultural bridges that can be constructed and, given mutual interests in the land, such opportunities are arguably nowhere greater than through the geosciences and Earth systems thinking – which returns to Anderson's simile, "the land is actually like a big book." The rich and symbolic imagery of the geologist echoes the art – and the mapping of the land – of indigenous peoples. Through walking the land and examining it on every scale, the geologist shares, in his own way, the intimate knowledge of the mosaic landscapes of the Western Pueblo, or Papunya cultures. Even the concept of time (itself a thorny issue for modern physics) has shared elements – a continuity with the deep past, and the importance of cyclical processes. The concept of "uniformitarianism" – that our planet's history can only be understood, and, indeed, anything be conjectured about its future, by careful observation of how it works today – remains fundamental; the rates, however, at which planetary changes have occurred remain the subject of debate. To what extent is the Earth's story one of slow evolution, an underlying equilibrium, punctuated periodically (and/or cyclically) by catastrophic events? Does, indeed, the evolution of life proceed via "punctuated equilibrium"? It is but a small step from here to a dialogue with indigenous beliefs in a natural harmony that must be re-established after disturbance.

Perhaps most important of all is the point that the disciplines of earth sciences are place-based – as is, indeed, the meaning of the word indigenous. The importance of place has been explored in fascinating detail by the Chinese-born geographer Yi-Fu Tuan, now aged 85 and an emeritus professor at the University of Wisconsin. In 1976, Tuan published his best-known book, *Topophilia: a study of environmental perception, attitudes, and values* (Tuan, 1974) – an examination of what he called "the grammar of environmental awareness." For Tuan, every example of the way each of us views the physical world tells a story of our belief system, and of how we form and express our world views. He departed from traditional geography to consider philosophical and humanistic geography, and particularly the concept of *place* as a "centre of meaning constructed by experience." In other words, that intimate relationship between individuals and place, sculpted by both culture and experience. As a telling illustration of this, Tuan wrote:

Truth is subjectively embraced as part of one's total experience and outlook. The distinction may be illustrated by the Hopi Indian's understanding of space. It differs from the static, three-dimensional structure of Western man. The Hopi can see that too. Only to him, the white man's view is one possible view whereas his own is true in the sense that it conforms to his total experience.

The following dialogue between the anthropologist Dorothy Eggan and her Hopi informant makes this clear. The Hopi says: "Close your eyes and tell me what you see from the Hopi House at the Grand Canyon." With enthusiasm Eggan describes the brilliantly colored walls of the canyon, the trail that winds over the edge of it reappearing and crossing a lower mesa, and so on. The Hopi smiles and says: "I see the colored walls too, and I know what you mean all right, but your words are wrong." The trail for him does not cross and does not disappear. The trail is only that part of the mesa that has been changed by feet. He continues: "The trail is still there even when you do not see it, because *I can see all of it*. My feet have walked on the trail all the way down. And another thing, did you go to the Grand Canyon when you described it?" Eggan says, "No, of course I didn't." The Hopi's answer to that is, "Part of you was there or part of it was here." Then with a broad smile: "It is easier for me to move you than to move any part of the Grand Canyon."

The spiritual and cultural value of land can only be explored through the eyes and minds of different cultures. The value of areas of consonance, and the possibility of learning from contrasts, so compellingly documented by Aikenhead and Michell (2011), is the subject of research in the academic sphere of education worldwide. In 2014, two entire issues of the *Journal of Geoscience Education* were devoted to the theme of "Teaching Geoscience in the Context of Culture and Place" (Apple, Lemus, & Semken, 2014). In their introduction to the theme, the editors wrote that

> Place-based education (a term introduced by Elder, 1998) refers to an approach that engages the sense of place by emphasizing local and regional surroundings, issues, and knowledge (i.e., place meanings); integrating experiential or service learning in the field or community if possible; foregrounding local relevance; fostering respect and concern for places (i.e., place attachment); and promoting environmental and cultural sustainability.

They quote from Gregory Cajete, Director of Native American Studies, and Associate Professor, at the University of New Mexico, as well as a member of the Tewa, a Pueblo Native American culture. Cajete has dedicated his career to designing culturally responsive curricula, and to building bridges between eurocentric and indigenous worldviews.

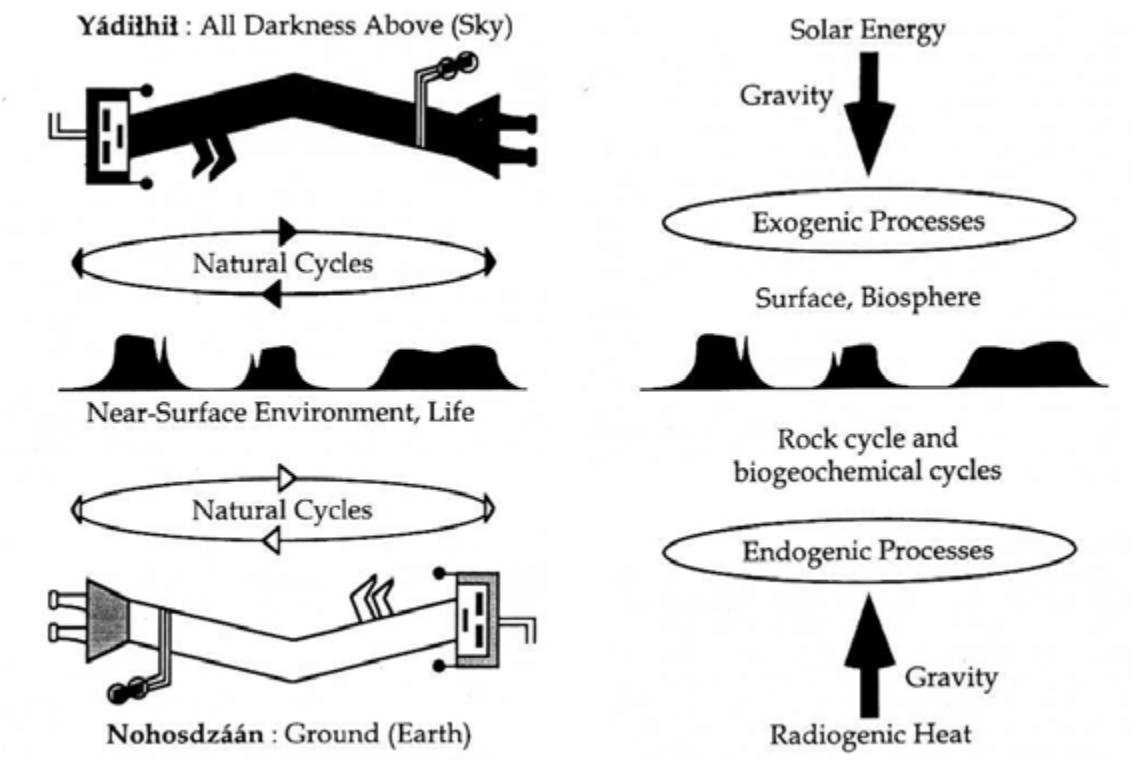


Figure 9: **Diné and geoscience Earth systems.**
Source: Steven Semken, Frank Morgan, Journal of Geoscience Education

In *Look to the mountain: An ecology of Indigenous education* (Cajete, 1994), he wrote that

> [T]he first way of thinking and knowing has to do with one's physical place. That is, one has to come to terms with where one physically lives. One has to know one's home, one's village, and then the land, the earth upon which one lives… For Indigenous people, this first type of thought begins the extension and integration of connections with Nature and other people in the community.

Steven Semken, quoted further above, is another pioneer in this field. Associate Professor of Geoscience Education and Geological Sciences at Arizona State University's School of Earth and Space Exploration, he has worked extensively with indigenous communities and developed cross-disciplinary and cross-cultural learning programmes. Semken explicitly recognizes the value of an Earth-system model as the basis for cross-cultural, place-based learning. In his 1997 paper, "Navajo pedagogy and Earth systems" (Semken & Morgan,1997), Semken, together with Frank Morgan of the Navajo Community College, described the analogies between the Navajo (Diné) model of natural systems and what they refered to as the "bilateral earth systems" model. The Diné concept of *Nohosdzáán* can be connected directly to the processes of the solid-earth systems, and *Yádilhil* to the fluid-earth system of water, atmosphere, and climate. The Diné recognition of cycles of disturbance to equilibrium, feedback, and the subsequent establishment of a new state of equilibrium corresponds to the diversity of the cyclical processes that sculpt our planet's landscapes. Figure 9 is Semken's illustration of this consonance.

While the emphasis here is on developing education curricula that resonate with both indigenous and non-indigenous students, the potential power of such research and these ideas reaches into the wider world. In *Bridging Cultures*, Aikenhead and Michell (2011) related the tale of a young Diné woman named Deborah, who enjoyed science at school and wished to apply this to becoming a physician and improving the health of her people. However, university biology presented profound problems of comprehension for her, conflicts that were intellectual, linguistic, and cultural: She told one instructor, "A lot of what you are saying I can't understand because it's not in my world." Only through good fortune and the understanding and creativity of instructors and colleagues did Deborah succeed. She succeeded because she achieved a reconciliation between two worldviews by learning "to distinguish between understanding a scientific idea and believing it." Although "It was some time before Deborah was able to accept the existence of both stories without having to sacrifice one over the other … Deborah finally realized that Diné tradition and Western medicine could be complementary and promote harmony at the same time."

4. CONCLUSION: VALUING THE LAND – KNOWLEDGE, WORLDVIEWS, AND OPPORTUNITIES.

Deborah's story, detailed above, together with the cross-disciplinary, cross-cultural messages of countless researchers around the world, is immensely powerful. But that power lies not only within the realms of formal education and in addressing the challenges faced by indigenous learners – but also as applied to society as a whole. When Aikenhead and Michell (2011) wrote that "science-shy students resist learning conventional school science that is mainly abstract, out of context, and seemingly impractical," that phrase "science-shy" can be applied – completely understandably – to large segments of populations as a whole, of whatever age or cultural background. The need for all societies to be aware of, and informed about, their planet and their land, their environment and its ecosystems, is indisputable and an essential component of "sustainability," commonly misused and misunderstood as that term may be. But awareness and knowledge are, more often than not, faced with the linguistic, hubristic, and cultural barriers with which eurocentric science has traditionally surrounded itself. The bridge potentially provided by the narratives and metaphors of indigenous knowledge, and the imagery of land as a book, is a powerful structure for exploration.

Furthermore, a bridge between knowledge systems offers global benefits beyond simply enhancing awareness – there is real, practical value to be gained. Indigenous knowledge of ecologies and biodiversity is ancient and deep, and directly applicable to issues that top-down eurocentric science has historically failed to deal with effectively. The Sahel, for instance, illustrates but one example of many in which traditional knowledge and agricultural methods have made profound contributions to ameliorating land degradation ("desertification") (Reij, Tappan & Smale, 2009; Rinaudo, 2012). Gary Nabhan, "ethnobiologist" and the W.K. Kellogg Endowed Chair in Sustainable Food Systems at the University of Arizona, has devoted his life to exploring and documenting what can be learned from traditional agrarian communities and the conservation of the links between biodiversity and cultural diversity. Echoing the recommendations of the 1999 United Nations Environment Programme (UNEP) report, *Cultural and Spiritual Values of Biodiversity* (Posey, 1999), Nabhan and his colleagues from the US and Mexico, focused on collaborative, cross-cultural, and cross-disciplinary projects with the Comcaac people of the arid lands of Sonora. The summary of their report, "The Importance of Indigenous Knowledge in Curbing the Loss of Language and Biodiversity" (Wilder, O'Meara, Monti, & Nabhan, 2016) stated that

> Biodiversity inventory, monitoring, and species-recovery efforts can be advanced by a dynamic collaboration of Western, citizen, and ethnoscience. Indigenous and local traditional knowledge of place-based biodiversity is perhaps the oldest scientific tradition on earth. We illustrate how an all taxa biodiversity inventory network of projects in collaboration with the Comcaac (Seri people) in northwestern Mexico is advancing not only biosystematics but also species recovery, habitat restoration, language conservation and maintenance, and the maintenance of traditional livelihoods. We encourage scientists to establish collaborations with indigenous and other place-based communities to better understand the wealth of knowledge held in local categorization systems. It is essential to not merely seek out one-to-one correspondences between Western and indigenous knowledge but also to recognize and respect the creative tensions among these different knowledge systems, because this is where the most profound insights and fruitful collaborations emerge.

Wilder et al. (2016) further concluded that:

> The complex nuances of local classification systems, both among the Comcaac and indigenous cultures worldwide, are a bountiful repository of understanding crafted over the millennia that is rapidly diminishing in scope and detail. By not fully honoring the real and potential value of indigenous science as it does professional academic and citizen science, our institutions risk ignoring the opportunity for consilience among the many sources of knowledge. The challenges we face both collectively as a species and independently as nations, societies, communities, and individuals are too great to not seek out knowledge that can advance our response to an impoverished world.

This is a powerful testimony to the value of building bridges between conventional and indigenous science. One practical example of this value is the potential treasure trove of pharmaceutical molecules awaiting discovery through indigenous knowledge of plant and microbial life in (although not limited to) arid lands.

Furthermore, developing this potential consonance lies at the very heart of UNEP, the United Nations Educational, Scientific and Cultural Organization (UNESCO), and the United Nations Convention to Combat Desertification (UNCCD; specifically this Global Land Outlook platform) ; intensifying connectedness is also something that has been explored by governments, academia, and non-governmental organization (NGO) initiatives around the world. Over recent times there has been increasing momentum to adopt an integrated landscape management approach – an underlying theme at the core of many of these bridge-building programmes. This is essentially a systems approach with the goal of improving planning and policy formulation, and is manifestly consistent not only with the scientific – and, specifically, geological – thinking discussed above, but also, importantly, with the fundamental holistic worldview of indigenous communities.

Any project with the aim of understanding the drivers of land change, optimizing land planning, and balancing land uses must surely begin with a comprehensive assessment of the perspectives of all stakeholders. A clear and explicit documentation of the contrasting and shared ways in which different stakeholders literally see and read the landscape (in its broadest possible sense), how they read the 'book', must be the foundation for the initiation of any such project.

In setting out a brief history of integrated landscape management theory, James Reed and his colleagues (Reed, Van Vianen, Deakin, Barlow, & Sunderland, 2016) noted that

> An integrated approach to managing landscapes is not a new concept, but rather one refined through multiple iterations during attempts to integrate social and economic development with biodiversity conservation and climate change mitigation. It is widely acknowledged that traditional communities have managed natural resources in a holistic manner for centuries to meet social needs.

Meanwhile, Sayer et al., in discussing their *Ten principles for a landscape approach to reconciling agriculture, conservation, and other competing land uses* (Sayer et al., 2013), described how

> "Landscape approaches" have gained prominence in the search for solutions to reconcile conservation and development tradeoffs, and the term has evolved to encompass a wide variety of interpretations. Early conservation theory promoted landscape-scale thinking… "People" and "society," however, were notably absent from such considerations, and, as a result, conservation has been beset by disappointments and failures.

Their fourth principle is a recognition of the multifunctionality of landscapes and their components, each of which is valued in different ways by different stakeholders: "Tradeoffs exist among the differing landscape uses and need to be reconciled."

The complexity and diversity of those landscape components, as geologists and ecologists are only too aware, are almost never completely understood, and often cannot be reconciled with the traditional compartments of conventional science and government agencies, or, at times, with the worldviews of stakeholders.

Reed et al. (2016) noted that "despite the widespread promotion of integration, aside from the rhetoric, researchers remain embedded within their disciplinary silos."

These challenges are not easy to overcome, but they are being actively addressed. Reed et al. (2016) described the application of a "continual engagement model and boundary spanning at several scales" to "support community and policy action with science" in the savannas of East Africa:

> This model helped change the discussion of the merits of land subdivision in this region at the community and policy levels. The most sophisticated level, and the most rarely implemented, was ''hybrid knowledge creation,'' wherein the facilitator, community members, and researchers created hybrid information together (policy makers were sometimes consulted in this process). From a community and policy perspective, this hybrid knowledge brought the reliability of scientific information into the community and policy decision-making processes. From a scientific perspective, this hybrid knowledge ensured relevance of the science and allowed a wider and deeper interpretation of the information collected.

The concept of "hybrid knowledge," the thoughtful integration of different perspectives, knowledge systems, and beliefs, is surely critical to achieving success – a challenge, certainly, but the building of bridges between silos and worldviews is no easy task. Reed et al. (2016) stressed that "A complete landscape assessment should account for the 'sense of place and identity' of landscape inhabitants" and that

> A landscape approach must attempt to not only understand the basic needs of local stakeholders but to foster empowerment of community members. By providing local stakeholders an active voice in the design and management of the landscape, it can be determined what people want and expect, rather than what they are prepared to accept.

The question remains, however, of how these bridges might effectively be built; what might be an integrated, trans-national, cross-cultural, pluralistic mechanism via which to do so, in order to explore their full potential. It might be hoped that such a goal could be incorporated into the implementation of the UNESCO's *2030 Agenda for Sustainable Development.*

In 2014, UNESCO published its "Roadmap for Implementing the Global Action Programme on Education for Sustainable Development" (UNESCO, 2014), the introduction to which declared that

> Rapid, sweeping, and long-lasting change is altering our planet's environment in an unprecedented manner, while societies are undergoing profound shifts in their demographic makeup and social and economic fabrics. Political agreements, financial incentives or technological solutions alone do not suffice to grapple with the challenges of sustainable development. It will require a wholesale change in the way we think and the way we act – a rethink of how we relate to one another and how we interact with the ecosystems that support our lives. To create a world that is more just, peaceful and sustainable, all individuals and societies must be equipped and empowered by knowledge, skills and values as well as be instilled with a heightened awareness to drive such change.

"Objective 1" is "to reorient education and learning so that everyone has the opportunity to acquire the knowledge, skills, values and attitudes that empower them to contribute to sustainable development." The phrase "to reorient education and learning" is both provocative and highly relevant to the ideas presented here, along with the goal of the *Education 2030* declaration, and framework for action (UNESCO, 2015), to "Ensure that education acknowledges the key role that culture plays in achieving sustainability, taking into account local conditions and culture as well as building awareness of cultural expressions and heritage, and their diversity, while emphasizing the importance of respect for human rights."

In short, the land is a book, to be read in different ways, with different translations. An understanding and integration of those different readings into a hybrid knowledge system must, surely, be a fundamental prerequisite for building the diverse bridges necessary for sustainable development. Alison Anderson and John Wesley Powell, together with today's geologists, share a deep awareness of the issues of culture and sustainability, and perceive the land as a book, a book not always easily decipherable but one whose value is worth reading, interpreting, and sharing. As Powell wrote elsewhere in his report (Powell, 1875) of his extraordinary journey through the Grand Canyon:

> Above are broken, ragged, non-conformable rocks, in many places sloping back at a low angle. Clambering over these, we reach rocks lying in horizontal beds. Some are soft; many are very hard; the softer strata are washed out; the harder remain as shelves. Everywhere there are side gulches and cañons, so that these gulches are set about ten thousand dark, gloomy alcoves. One might imagine that this was intended for the library of the gods; and it was. The shelves are not for books, but form the stony leaves of one great book. He who would read the language of the universe may dig out letters here and there, and with them spell the words, and read, in a slow and imperfect way, but so as to understand a little, the story of creation.

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