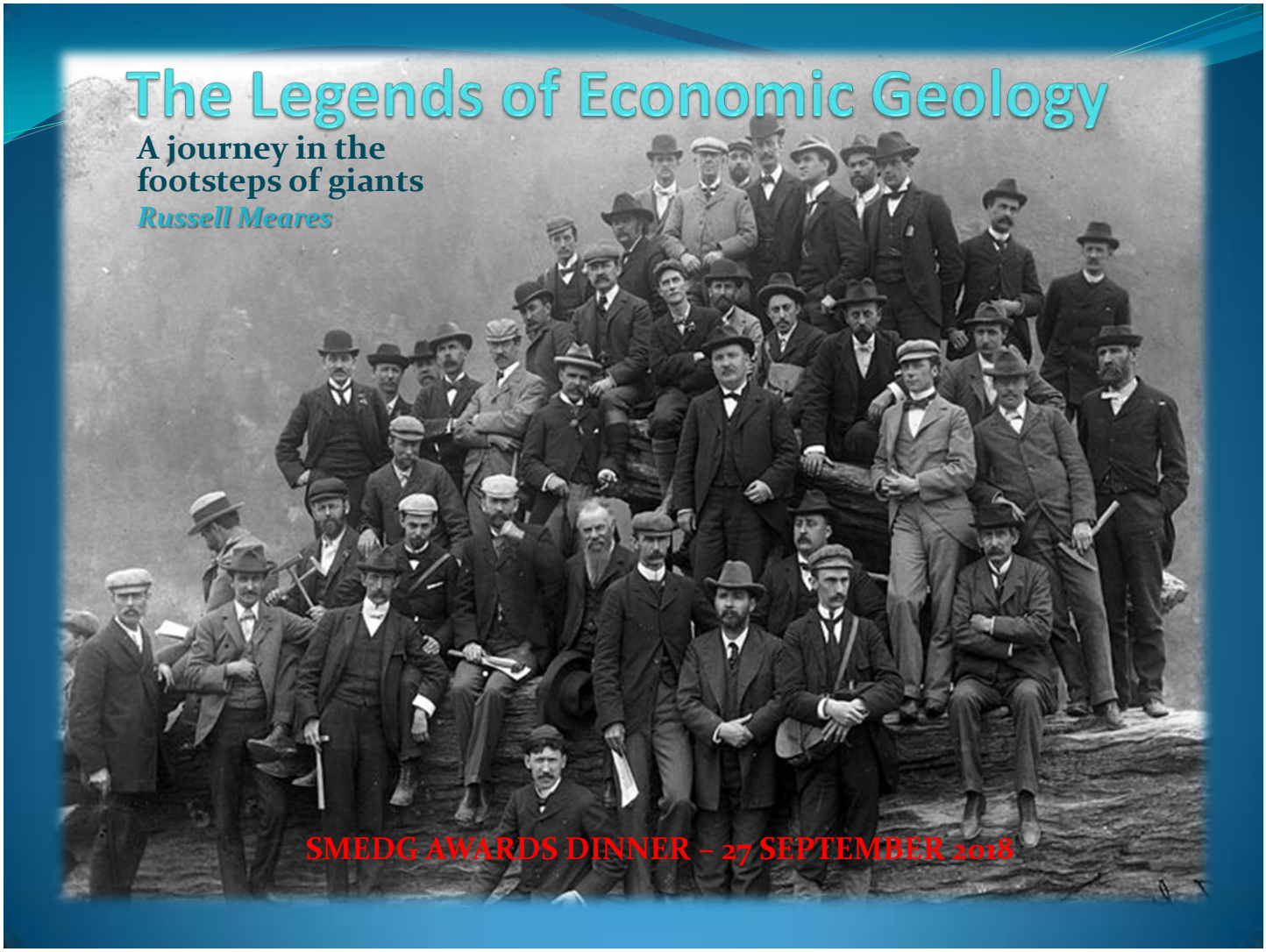


"**The Legends of Economic Geology**" are my heroes because I have walked in their footsteps throughout my career - so I thank the SMEDG Committee for this opportunity to share my passion with you - and I congratulate them on once again organizing our Awards Dinner as we pay tribute to our own **Legends of SMEDG !**

Most presentations these days start with a disclaimer, and mine is that the selection of my Legends is very personal. All are great geologists and explorers, who listened to the rocks and who inspired me and many others. Most lived in the days before Facebook, so I've had a ball digging into their amazing lives and careers, and discovering some interesting and quirky back-stories along the way.

While I was doing my research, I was constantly reminded of a couple of lines from a poem written around 1760 by the English soldier and poet Thomas Osbert Mordaunt which goes:

"One crowded hour of glorious life

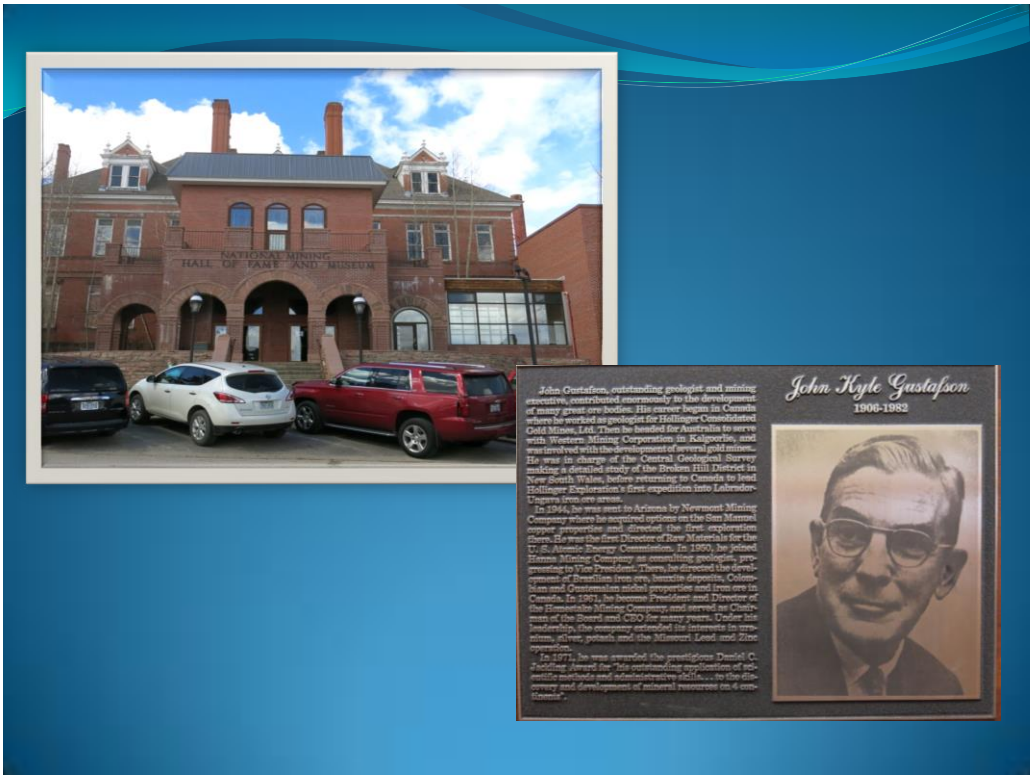
Is worth and age without a name"

And I can assure you that my Legends shared many many Crowded Hours between them !

So let's hit the road, look at some rocks, and meet our Legends……

This talk came together during a two-week road trip which my wife (Win) and I did through the National Parks of southern Utah, and the gold and silver mining heritage towns of southwestern Colorado. We started our journey in Salt Lake City and ended two weeks later in Denver, where I had arranged to visit the team at the headquarters of the *Society of Economic Geologists*. Along the way we visited the Zion, Bryce Canyon, Arches and Canyonlands National Parks – all in the catchment of the Colorado River.

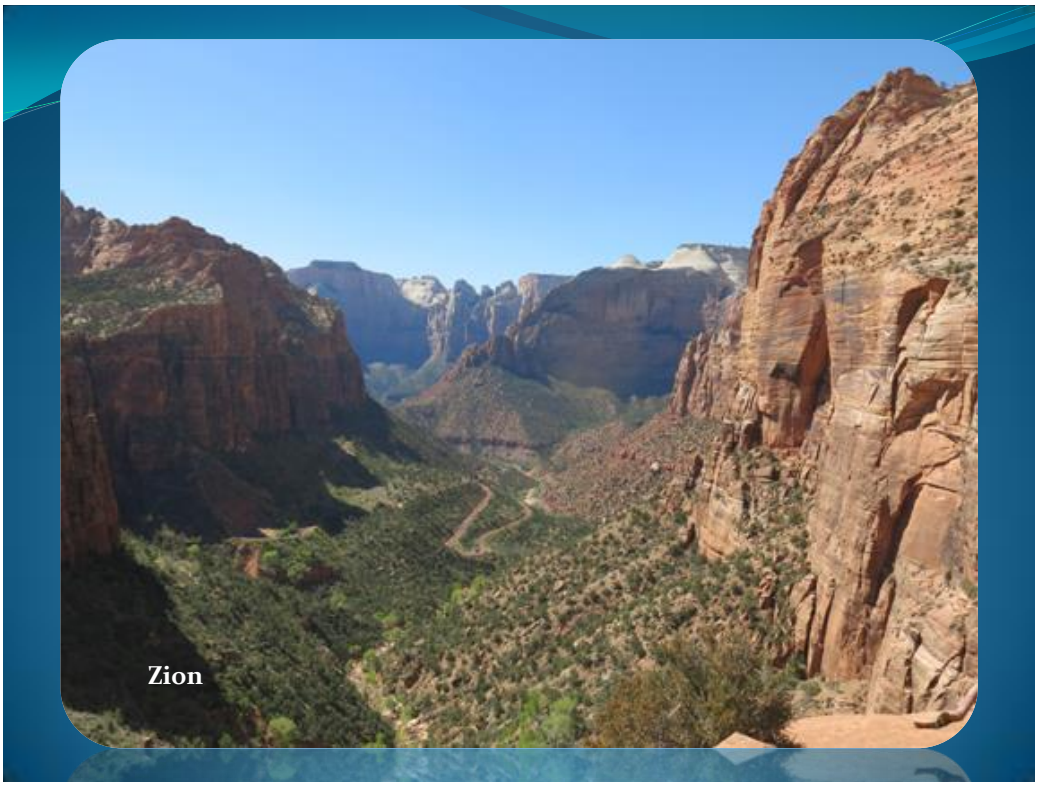
I was inspired to create this talk near the end of our journey - at the *National Mining Hall of Fame and Museum* in Leadville, Colorado – west of Denver. Here 240 bronze plaques commemorate the careers of the international pioneers of mining, metallurgy and economic geology. That was my "light bulb moment" to create this talk. This is a typical plaque, and they go right back to Agricola in the early 1500's.



So let's start our road trip…….

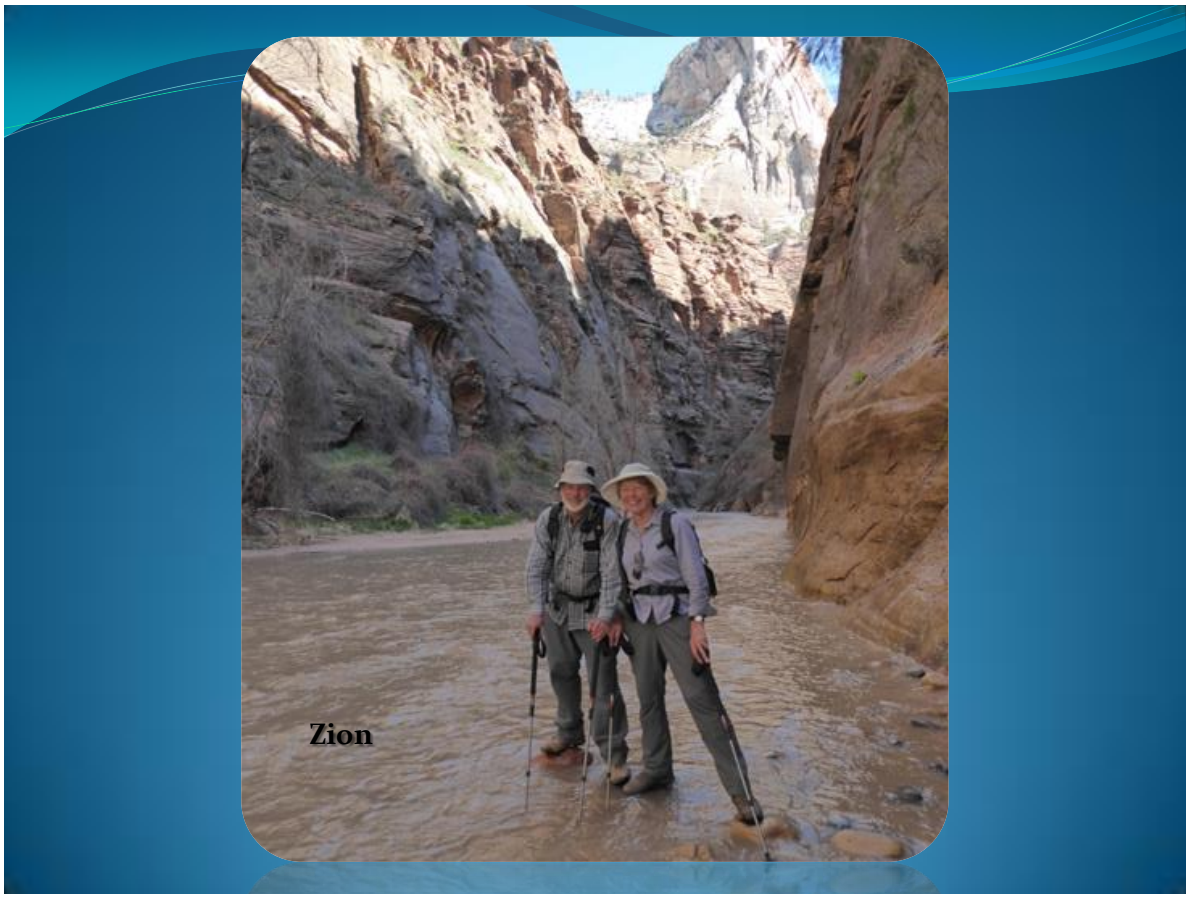
UTAH NATIONAL PARKS

Zion National Park

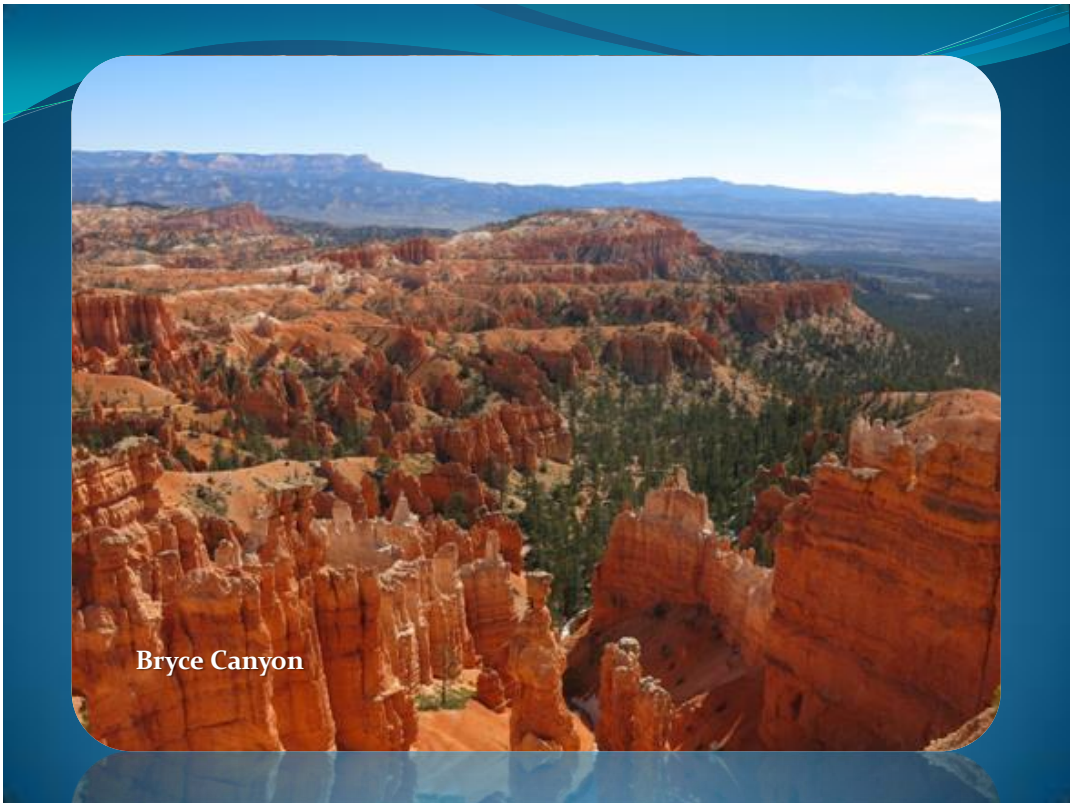


Here a 700m thick Jurassic (150-200My) sandstone sequence is akin to the Blue Mountains "on steroids".

In the Jurassic, Utah was just north of the Equator and was a huge sandy desert (like the Sahara) – and has the world's best exposures of cross bedding.



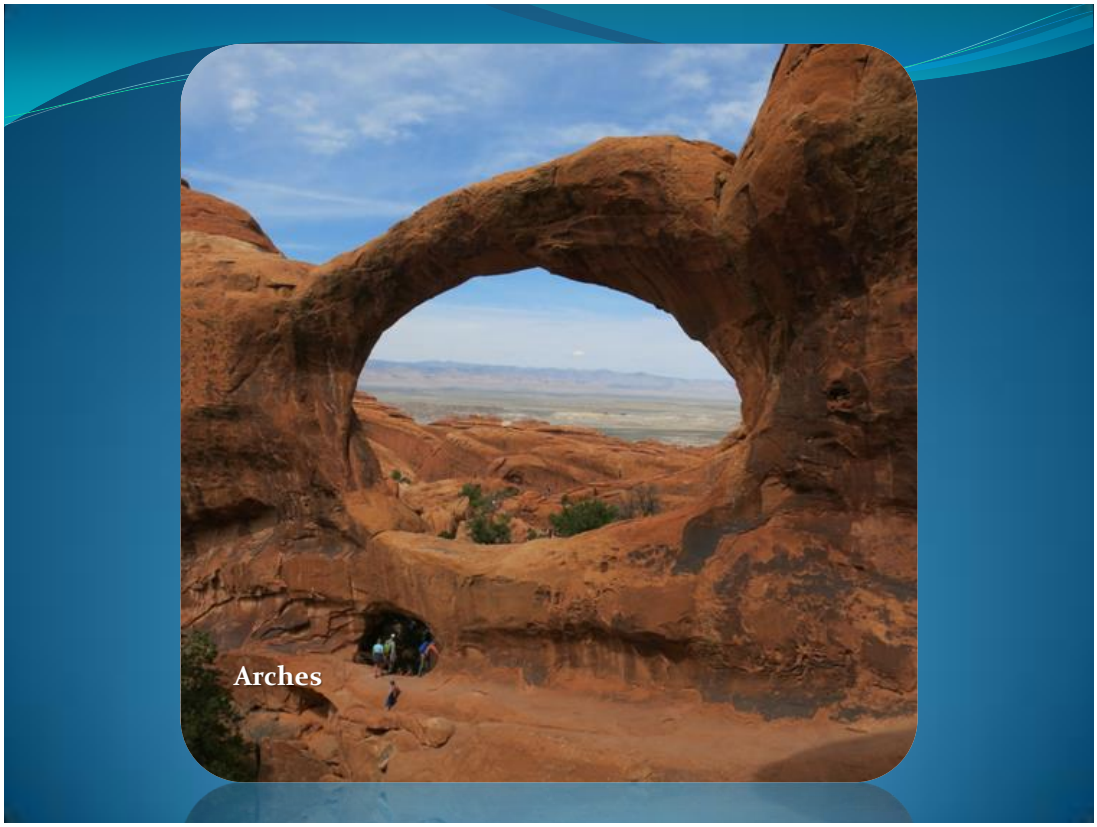
Bryce Canyon National Park



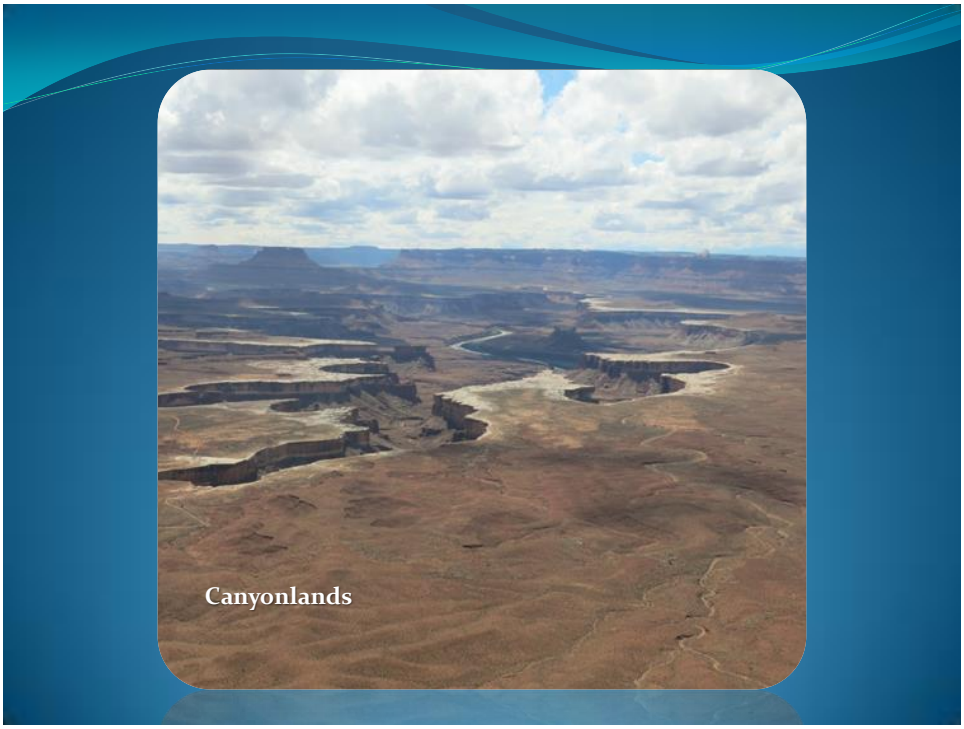
Here we are up near the top of the sedimentary pile – these are 50My old Tertiary sandstones. The erosion process is similar to that at Bungle Bungles in the Kimberley, with the edge of a plateau being slowly eaten back, but with the added freeze/thaw process here at Bryce Canyon. The small weathering spires are called “hoodoos”.

Arches National Park

We are back in the Jurassic, with over 2,000 amazing arches preserved in this National Park. Their formation is the result of a combination of lithology, a unique fracturing pattern in response to folding of underlying thick salt layers, and erosion.

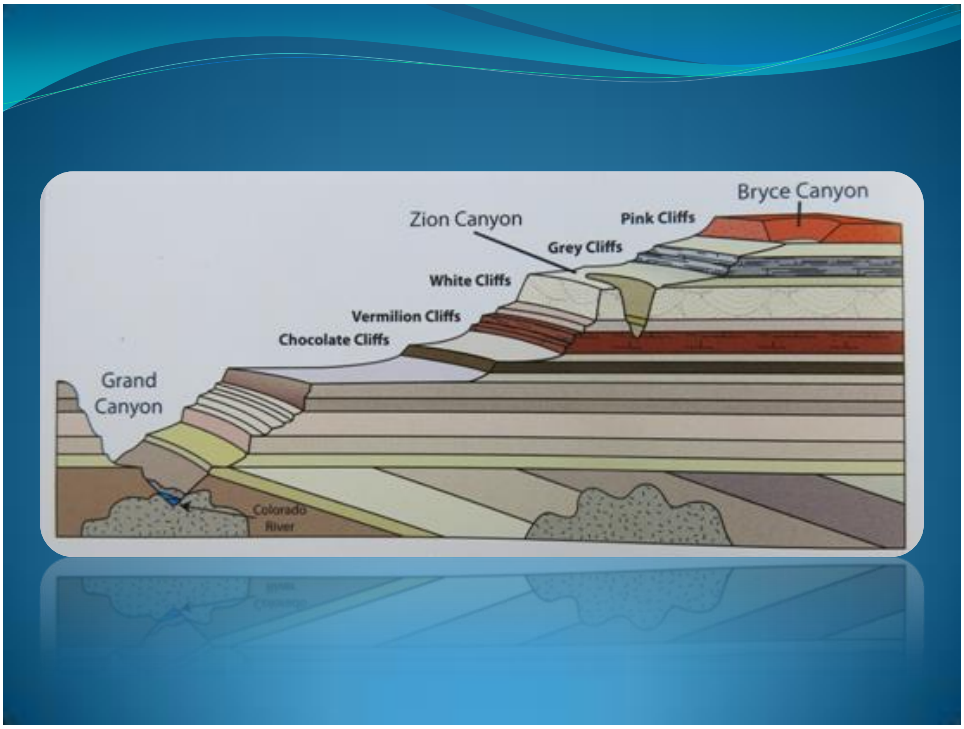


Canyonlands National Park



At the confluence of the Green and Colorado Rivers – this is the upstream end of Grand Canyon erosional process, where 17 mid-Palaeozoic rock units are exposed.

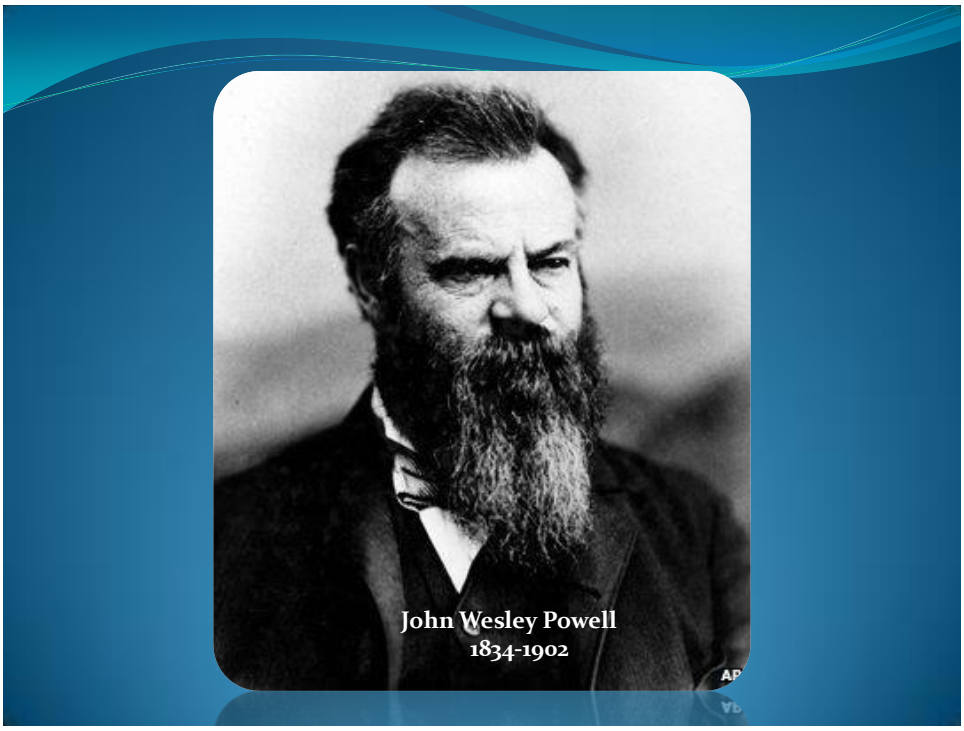
The Giant Staircase



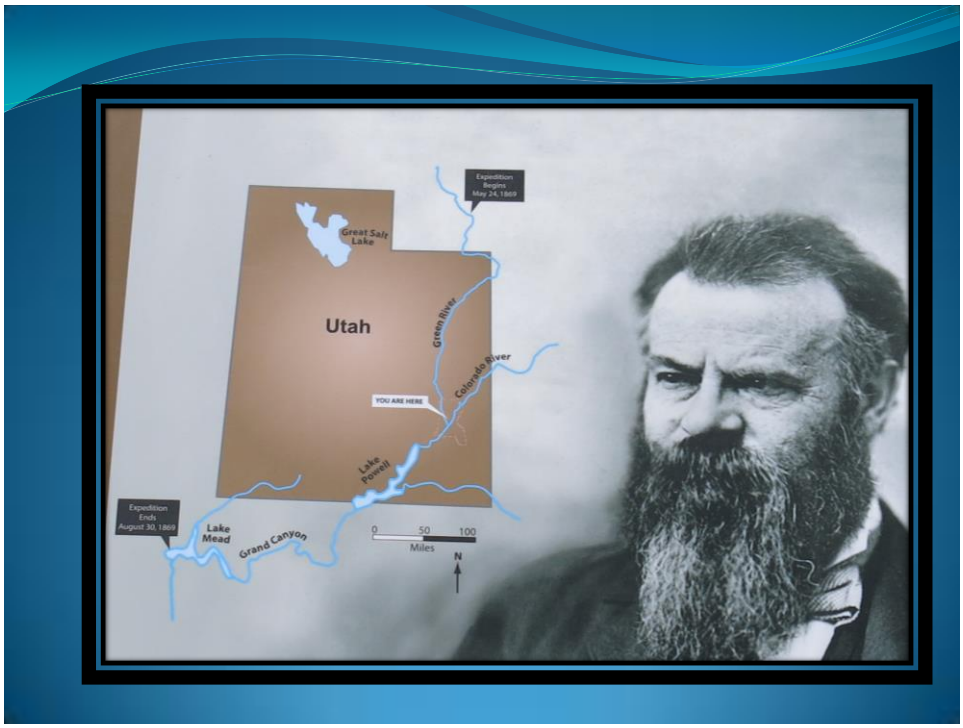
This regional cross section shows 1500m of elevation difference, and an 1800 million year time span, from 2 billion year old basement rocks in the bottom of Grand Canyon, to the youngest Tertiary rocks at Bryce Canyon.

So now we've reached the Grand Canyon, let's meet our first Legend…….

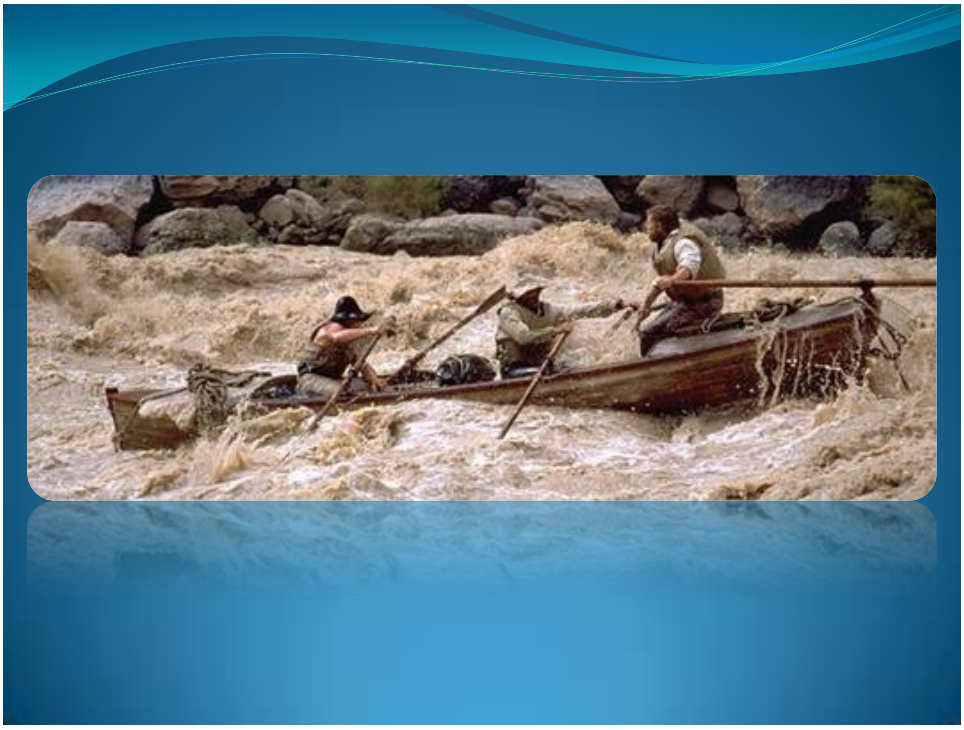
JOHN WESLEY POWELL (1834-1902 = 68 years)



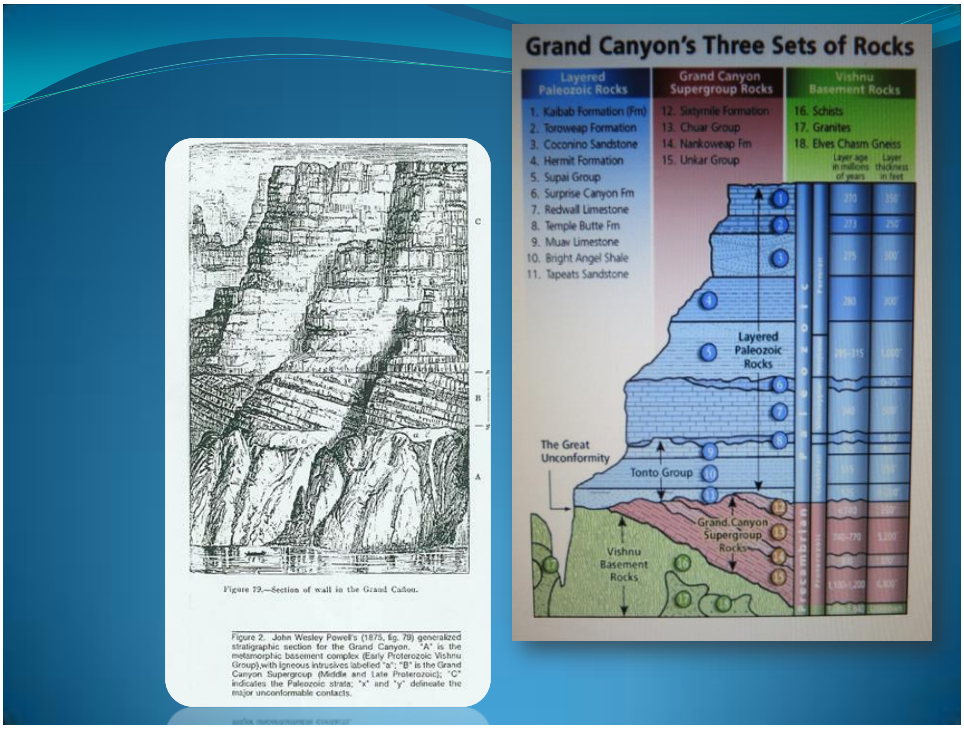
John Wesley Powell had an amazing life as a geologist, as an explorer, and as a soldier. Because of his rugged looks, they said about him……."*The years have been good to him, but the weekends have certainly taken their toll*" ! He is best known as an explorer, because at the age of 35 he led the first expedition to navigate through the Grand Canyon in 1869. Back then the Grand Canyon was a large blank space on the map of America.



With 10 men in 4 boats, over a period of three months, they travelled 1,500km down the Green and Colorado Rivers – starting in Wyoming, traversing across all of Utah, and finishing in Arizona – and battling through over 400 hundred sets of rapids, and portaging around in excess of 60 waterfalls - most of the time soaking-wet and in fear of their lives.



In fact, half way through the expedition, three men decided that the only way that they would survive their endless nightmare journey was to climb the 1,500m high cliffs and walk out – they were never seen again !



On the left is Powell's 1869 sketch stratigraphic column he saw in the cliffs, next to a modern-day version – a good match ! As an adventurous geologist, Powell loved the whole experience – so much so that he repeated it two years later with members of his family !!

Powell was born in Illinois, and he loved adventures – he spent 4 months walking across Wisconsin, and he rowed over 2,000km down the Mississippi River from Minnesota (up near the Great Lakes) down to the Gulf of Mexico – so he was well-prepared for the Grand Canyon trip. He was clearly a restless man of action, because he spent 7 years studying various courses at college in Illinois, but never graduated !

His early life was overtaken by the American Civil War in 1861 when he was 27. He enlisted as a Private, and fought in many battles for the North. He rose to the rank of Major – and for the rest of his life he was called "Major". This was followed by a number of expeditions in the Rocky Mountains, and then by the Grand Canyon expeditions in 1869 and 1871.

After his intense lobbying for the establishment of a Federal, centralized, geological survey, in 1881 Powell became the 2nd Director of the USGS, a position he held for 13 years – not bad for someone who never completed his geology degree !

From Powell's experiences in the rapidly-opening West, he understood the importance of policies to promote responsible land and water management – starting with good topographic maps and good geological maps. So during this third stage of his career, he was also a leader in the development of government policies about the responsible release of public lands and developing policies to protect the Indian tribes – based on his own experiences of their culture and language.

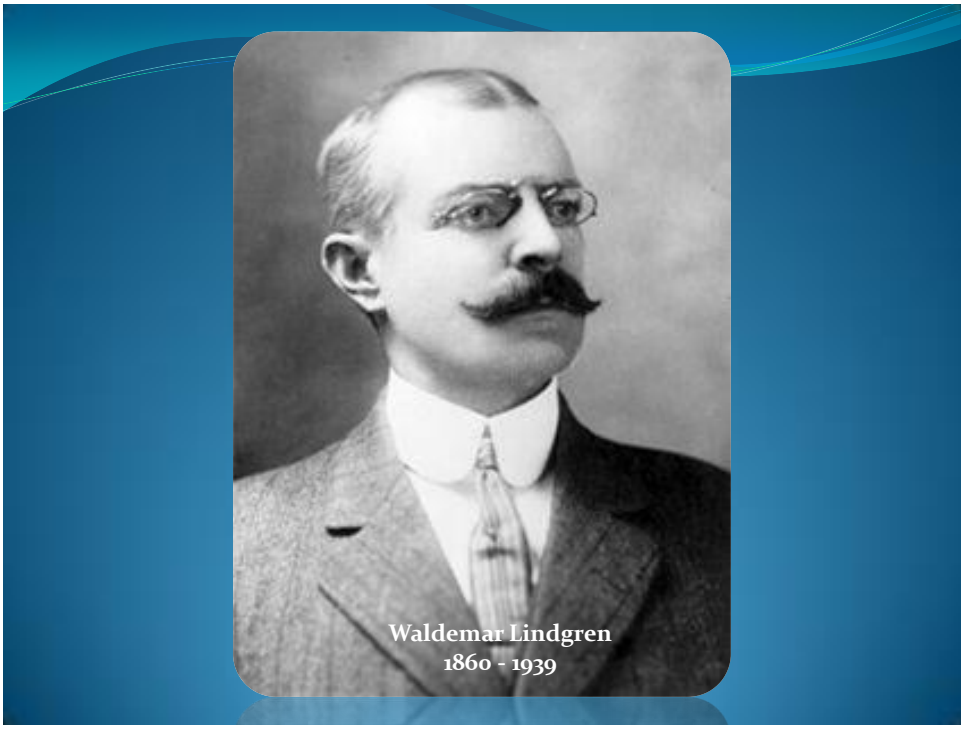
That's Powell near the centre of the above photo – with the beard and without a hat. The chap up the top in the white cap and the grey jacket is Sir Archibald Geike – head of the British Geological Survey – who appears later in our story.

In recognition of his contributions to science, Powell had the mineral "Powellite" named after him. The USGS established the *John Wesley Powell Centre for Analysis and Synthesis* – this is a research facility promoting innovative thinking in systems that drive planet Earth, through collaboration between geoscientists and the other scientific disciplines – just as Powell had done when he ran the USGS.

Finally, in recognition of his contributions to America, he was buried with other American war heroes and Presidents at the *Arlington National Cemetery* in Virginia, where his tombstone simply says "Soldier, Explorer, Scientist".

So let's meet now our second Legend…….

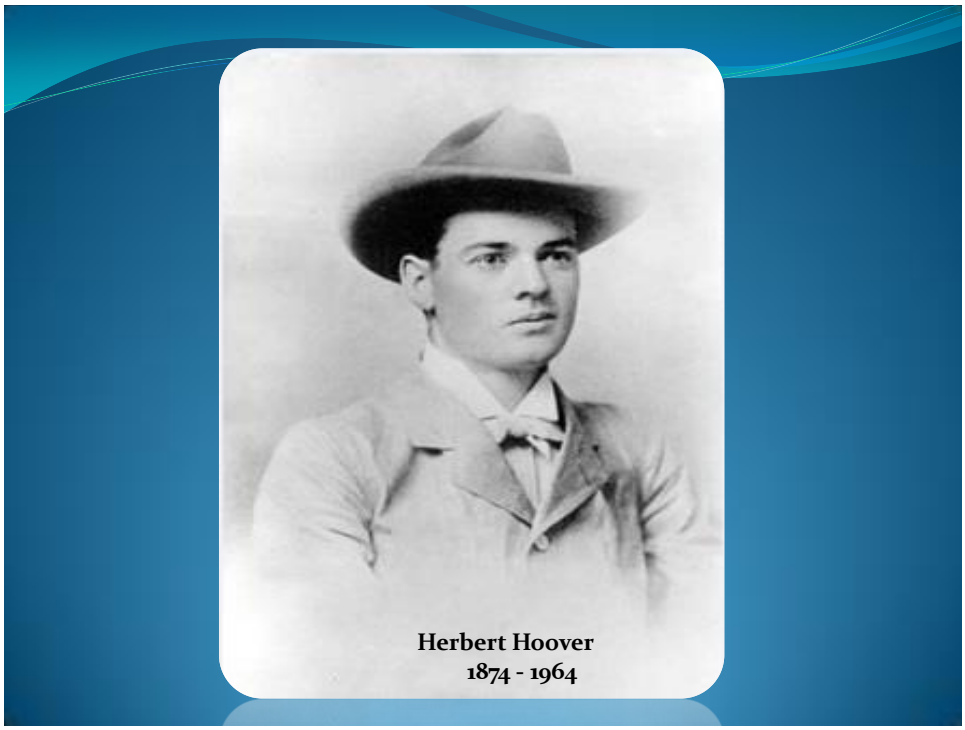
WALDEMAR LINDGREN (1860-1939 = 79 years)



I trust that you all had Lindgren on your own list of Legends, because he is known as the "Father of Economic Geology".

Lindgren was born in Sweden in 1860. He had a keen interest in minerals and mineral collecting from boyhood, and throughout his brilliant career he regarded the petrological microscope as important as his rock hammer. He was educated at the famous *Freiberg Mining Academy* in Germany – graduating in Mining Engineering (shock, horror !). Lindgren traveled to America to work initially as a geologist/engineer for a large railroad company – at the time of building the first railroads across America. While John Wesley Powell was the Director of the USGS, Lindgren was recruited to join USGS in 1884, and worked there for 28 years, rising to the position of Chief Geologist.

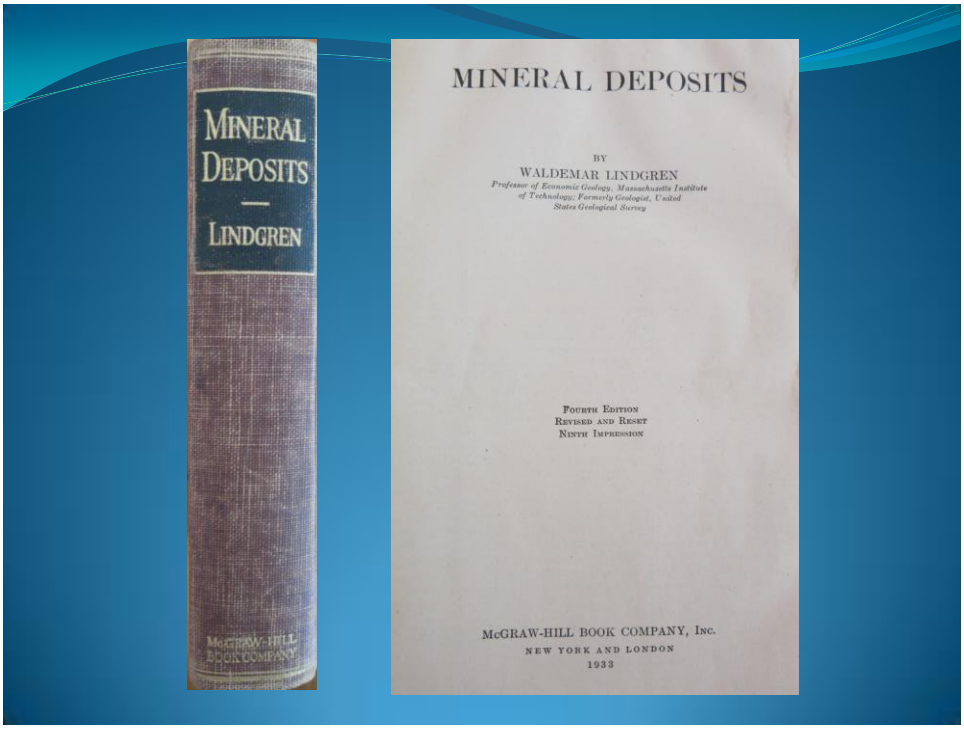
He initially studied gold and silver deposits of the Rocky Mountains, with a growing interest in the mineralogy and genesis of these deposits. Lindgren needed a field assistant to help him in this work, so he hired this student from Stanford University. This student worked for three summer vacations with Lindgren in investigating the gold deposits of the Sierra Nevada Range in California. He had big ambitions, and after graduating he worked as a Mining Engineer - managing and investing in mines around the world.



The student was Herbert Hoover, who went on to become the 31st President of the United States. Lindgren was so impressed with Hoover's capabilities, that he invited Hoover to be the joint author of the technical papers about their work - putting Hoover's name first. Later in life, Hoover said…… "*that no subsequent honour puffed him up as much as being co-author with Waldemar Lindgren on those maps and reports*" !

In 1905**,** with some colleagues, Lindgren helped establish the scientific journal they called "*Economic Geology*" to publish their papers, and today it is the journal of the *Society of Economic Geologists (SEG)* – which itself was not founded until 1920.

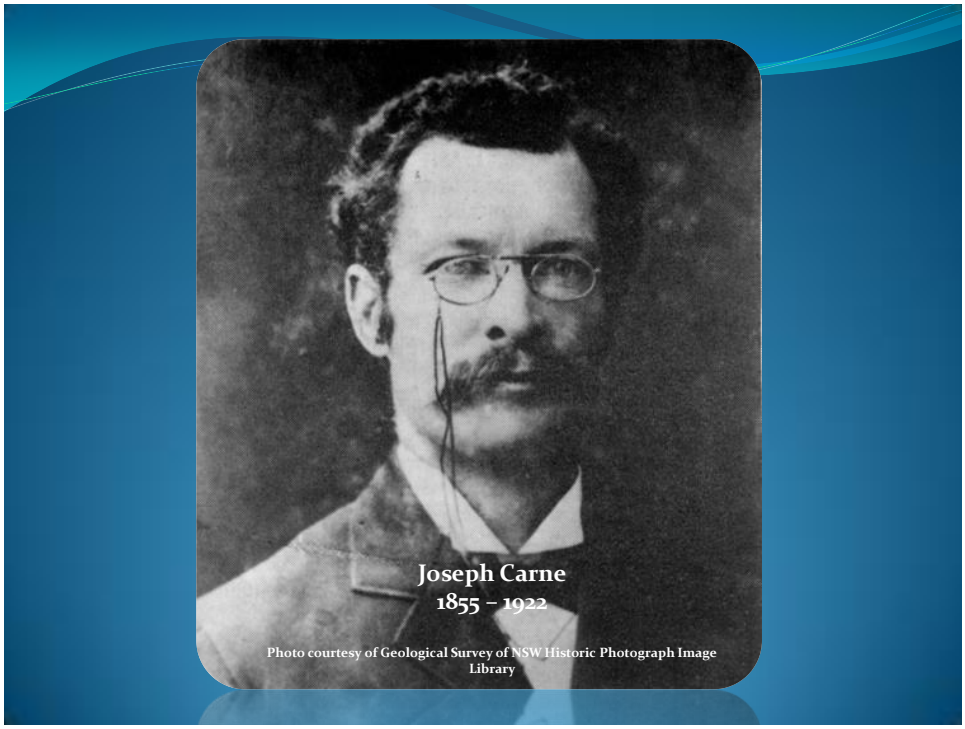
In 1912 Lindgren was appointed *Professor of Economic Geology* at the *Massachusetts Institute of Technology* where he wrote his famous landmark textbook on economic geology called "*Mineral Deposits*" – which many of us still have in our libraries. In this work he outlined the first system of the classification of ore deposits, the methods of ore deposition based on the physical and chemical conditions of ore formation, and the igneous source of ore fluids (= "hydrothermal"). In the 4th and final edition of "Mineral Deposits" in 1933, he was the first to use the term "epithermal" and describe that family of precious metal deposits



Lindgren was held in such high regard by his peers, that in 1924 he was elected as the President of both the *Geological Society of America* and the *Society of Economic Geologists.* The mineral "Lindgrenite" was named after him, and in 1928 he won the *SEG's* highest award for a lifetime of achievement – the Penrose Gold Medal. Lindgren wrote over 200 papers, and can truly be called "*The Father of Economic Geology*".

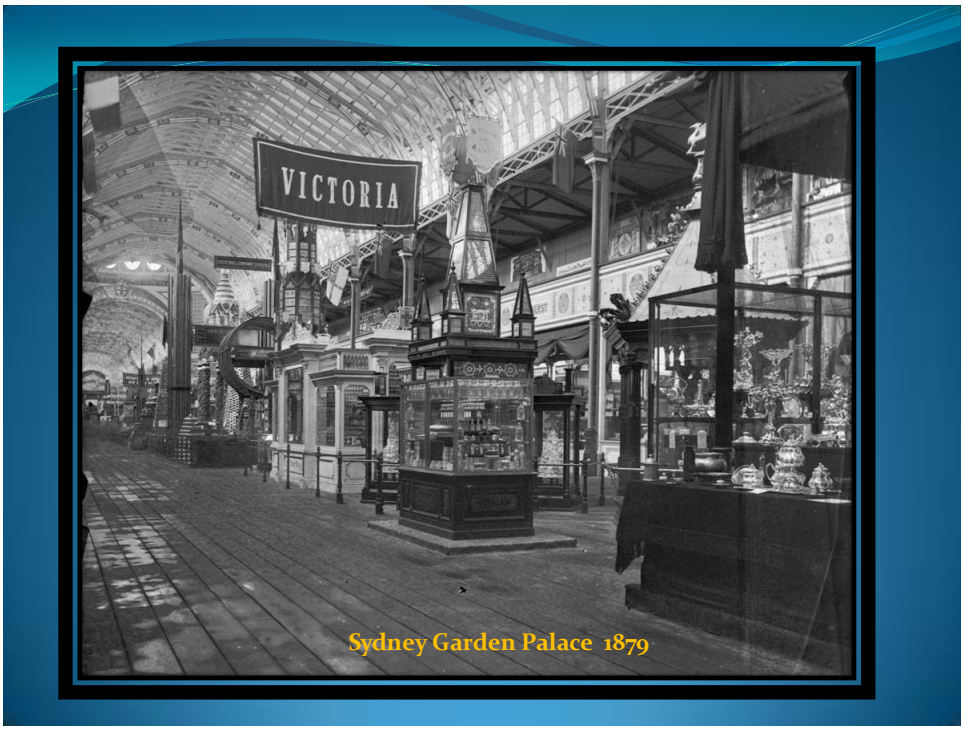
Let's head closer to home to meet our third Legend…….

JOSEPH CARNE (1855-1922 = 67 years)



Joseph Carne had an illustrious career at the *NSW Geological Survey* – where he worked for 40 years, being the first to investigate all the known mines and mineral occurrences of NSW – a huge task ! He was born in the Riverina, and his early life was spent in the bush as a stockman in the outback of NSW and Queensland – which provided him with the bush survival skills he would later draw on during his career as a geologist. It was at this time he contracted the eye disease "Sandy Blight" (we call Trachoma) – so he rode over 400km on horseback to catch the Cob & Co coach to Sydney for treatment. Although he recovered, his sight was permanently affected – not a good start to a career that required keen observation !

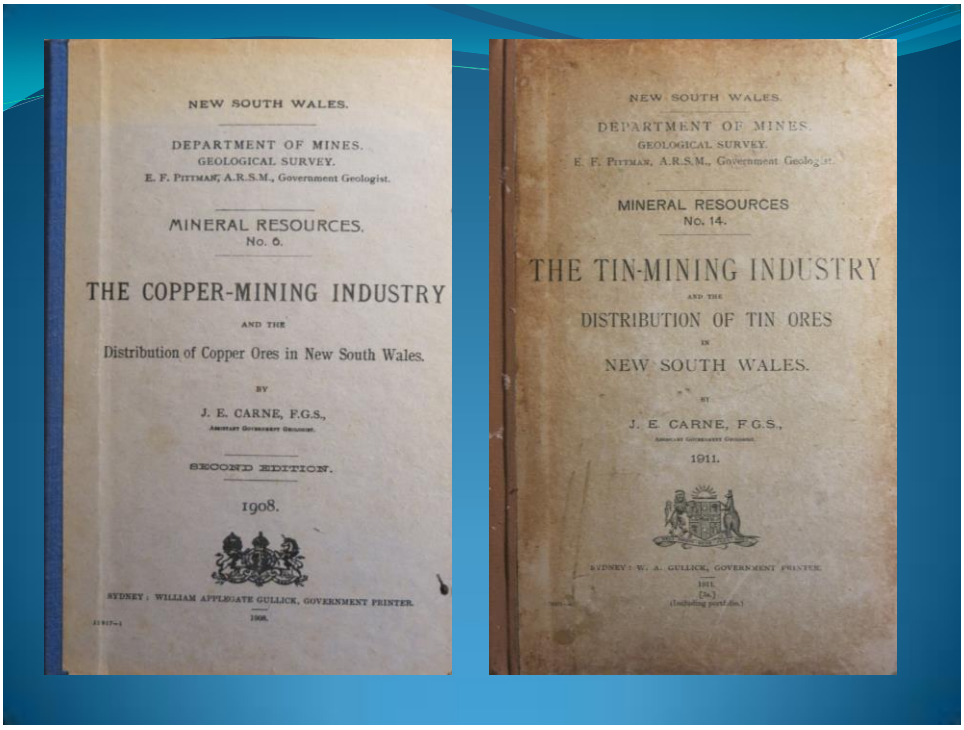
In Sydney he met Charles Wilkinson – the Government Geologist and head of the newly created NSW Geological Survey – who persuaded him to study geology at the Sydney Technical College. Carne joined the Survey in 1879, and made many landmark contributions in various roles in his 40 years at the Survey. Carne's first appointment to the Survey was as the Museum Curator, assembling the rock and mineral collections for the *Geology and Mining Museum* in Sydney, in preparation for a series of impressive displays by NSW at the international "Expositions" (World Trade Fairs) that were held around the world between 1879 and 1893.



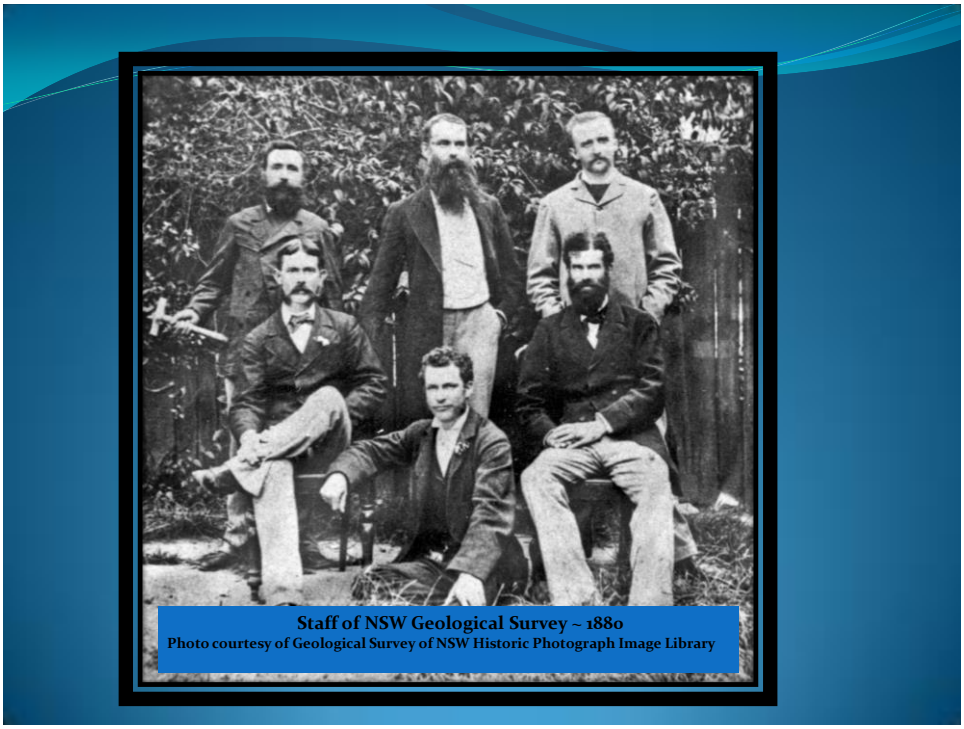
Sydney Garden Palace 1879

The first public display of Carne's diligent work was at the "Garden Palace" in Sydney. This was a huge glass structure akin to Sydney's Queen Victoria Building – erected in the Royal Botanic Gardens. Unfortunately for Carne, he was on his honeymoon when it was burnt to the ground in 1882 – so he had to rush back to work and start building the collection from scratch again – a three year task ! But Carne's diligence and hard work were recognised, and he was appointed as a Geological Surveyor in 1892.

His output as a geologist visiting, inspecting and recording thousands of mines and mineral occurrences throughout NSW was legendary – especially when it was done with only the most basic of maps and a compass, and travel was either on foot, by horse, by Cobb & Co coach, or by train. Carne's earlier experiences as a stockman certainly equipped him well for this role. It is worth noting that the Survey was not given approval by the NSW Treasury to buy its first car until 1937 !



He wrote up his investigations in a series of metallogenic reports (such as these two), covering the tin, copper, tungsten, antimony, chromium and limestone deposits of NSW. These were his two "landmark" reports, which are still referred to today. They include not only detailed descriptions of each mine, trench or pit which Carne visited, but also introductory chapters describing the mineralogy, worldwide deposit types, metallurgical treatment, and world markets for each metal – an absolutely amazing task, 100 years before Google !



This is a photo holding many stories……young Carne is seated in the centre of the front row. Going anti-clockwise from Carne we have Charles Wilkinson (Chief Government Geologist), Charles Cullen (fossil

collector), Wilkinson's brother, Lamont Young (the geologist who later in 1880 disappeared on a field trip on the NSW South Coast and after whom Mystery Bay is named), and Edward Pitman (geologist).

All of us have to work for difficult bosses at some stage in our careers, and Joseph Carne was no exception. For much of his career at the Survey, his boss was Edward Pitman, whom Carne succeeded as Government Geologist in 1916**.** Carne had risen to the top role in the Survey through his dedication and his hard work, and was described in his obituary as "*possessing a charm of personality which endeared him to all those who were brought into association with him*". By contrast Pittman was only promoted to the top role through the intervention on his behalf by the Premier of NSW (Sir Henry Parkes). His authoritarian leadership style alienated him from his staff, placing extraordinary burdens on his subordinates, in particular his successor - Joseph Carne.

I have spent many days in the bush with Carne's reports in my hand trying to discover NSW's next big mine. I am personally in awe of this man, who to me epitomized the very character of a true Legend, in both personality and achievement.

Let's now jump to the modern era and meet two of our '"Living Legends"……..

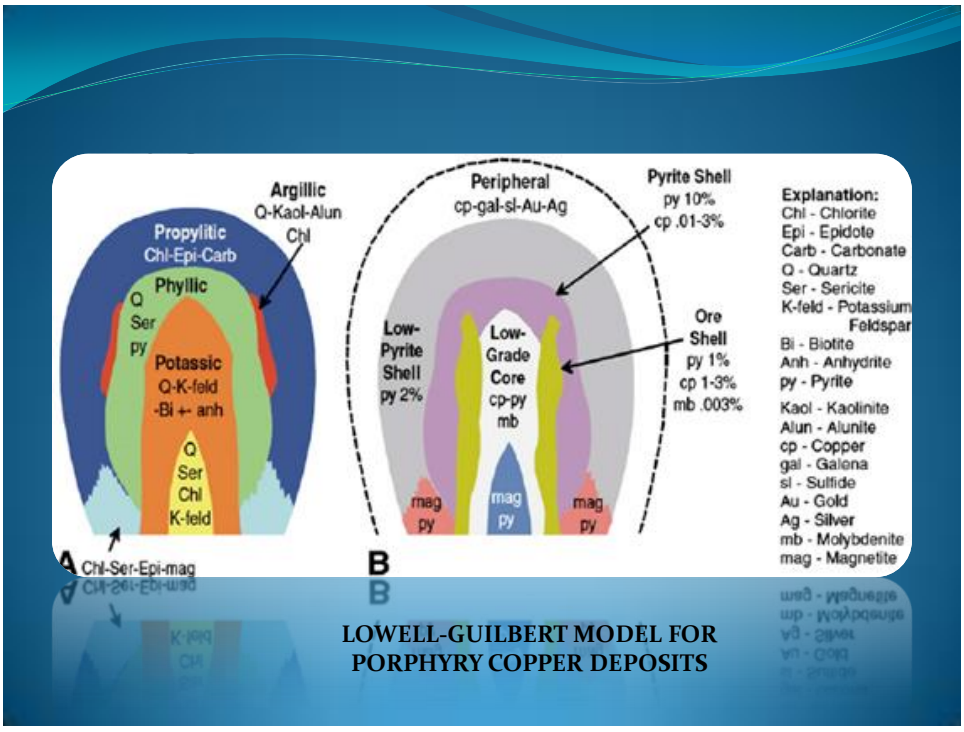
DAVID LOWELL (1928 –

David Lowell is regarded as the greatest economic geologist and mine finder of our generation. He's the "Don Bradman" of economic geology because he has discovered 17 orebodies in his career ! He has been an independent consultant since 1961, and up until 1990 he had worked for 110 companies in 26 countries – mainly in exploration for porphyry copper deposits.

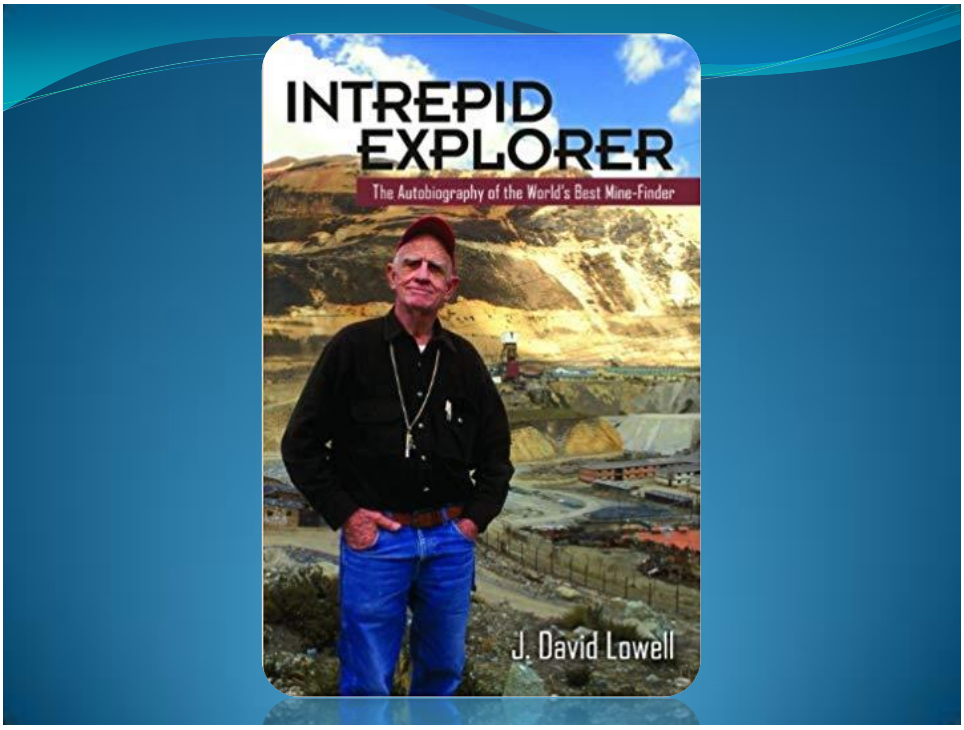
David Lowell was born in Arizona in 1928, so he is now 90 and he is still kicking rocks ! His early contact with rocks was hand-sorting ore samples at his father's silver mine in Arizona. His undergraduate degree was in Mining Engineering at the University of Arizona, and he later completed a Master of Science degree in Geology at Stanford.

His early career was spent searching for bulk low grade copper deposits in southwestern USA for Asarco and the Utah Development Company, and during this work he recognised patterns in the mineralization and alteration styles that were common to many deposits. The first test of his ideas was in 1965 when he was working for Newmont looking for extensions to the San Manual copper deposit in Arizona. Based on his developing theories, he postulated that the known San Manual deposit was half of a huge inclined cylinder of low grade copper ore, and that the other half had been displaced by faulting. Newmont wasn't interested in this crazy hypothesis, so Lowell sold the idea to a Texas oil company (Quintana), which paid him a finder's fee of US$120,000. Lowell then implemented his ideas and drilled the discovery holes for Quintana into what became known as the Kalamazoo copper deposit. Newmont then bought-back into the operation, which as Magma Copper became a big cash-cow for BHP.

In 1970, with his colleague from the University of Arizona (Professor John Guilbert), they formalized their ideas on this geological model for porphyry copper deposits. It is called the Lowell-Guilbert Model which describes the three-dimensional distribution of mineralization and alteration in porphyry copper deposits – and has been the blueprint for many more discoveries around the world.



In recognition of their contributions, both Lowell and Guilbert were awarded the SEG's Penrose Medal.



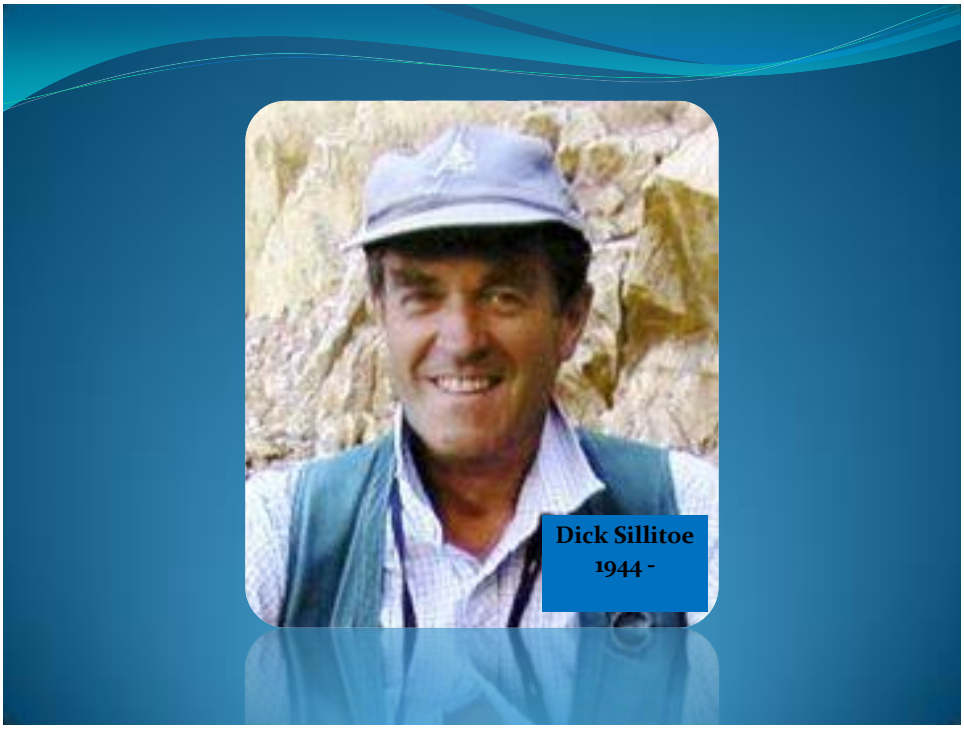
Lowell's list of discoveries includes the Dizon and FarSouthEast deposits in the Philippines, and from 1974 he turned his attention to applying his theories to the under-explored copper belts of South America. In Chile he discovered the Zaldivar and Escondida copper deposits – the world's largest - for which he was paid US$4.5 million. Among his other South American discoveries are San Cristobel, Pierina and Toromocho. At a party in Santiago, he met the Canadian investment banker – Catherine McLeod-Seltzer – who became his financier, and showed him how to capitalize on his exploration discoveries by building companies around them.

His intuition and hard work have made David Lowell a very wealthy man – his estimated wealth from his discoveries is now in excess of US$150 million. He has generously "given back" by funding a number of educational programs for geologists in America, including at his old Alma Mater - the University of Arizona. Above his desk he has a sign which says it all……."*Orebodies are found in the field – not the office*" !

He has a theory as to why major mining companies don't make discoveries as efficiently as prospectors like himself do. To quote him……"*Major mining companies have a "don't make mistakes" approach, which doesn't fit in at all with the profile of the mad scientist like me who discovers mines. When something like one in 500 good-looking targets will become a mine, a successful explorationist needs permission to be wrong 499 times ! If there's anything my career says about me, it's that I'm very good at being wrong* !"

And let's meet our fifth Legend…….

DICK SILLITOE (1944 -



Dick Sillitoe is a world-renowned London-based consultant economic geologist – who has probably seen more orebodies than any other person – ever ! His expertise is in porphyry copper and gold deposits, and epithermal gold deposits. Since 1971 he has consulted for more than 300 companies, and 11 international governments and agencies - working in over 100 countries. I can confidently say that he has more frequent flyer points than all of ours combined ! Dick is well-known to many people in this room, and he was our Keynote Speaker at the SMEDG *Symposium on South America* in 1996.

Dick studied geology at the *Royal School of Mines* in London, where he completed his PhD in 1968. Dick's initial exposure to porphyry copper deposits was in Chile, where he worked for the *Geological Survey of Chile*, and this was the start of a lifetime of assignments in South America.

He is an expert in deposit modeling using field observations and drill core logging – which means that he can visit an exploration prospect which only has a few drill holes, spend a day or two in the field – and draw conclusions about the type and size of deposit that may be present there – and importantly, where to site the next drill hole ! A bit like a jigsaw puzzle expert who can visualise the whole completed jigsaw puzzle when he (or she) has only seen the first few pieces.

My personal experience of this was when I was Exploration Manager for Goldfields in PNG in the early 1980's. We had purchased the Wau gold mine near Lae, and we had engaged Dick to tell us what potential it had, and where we could find more ore. Dick worked with Max Baker and Bill Brooke for a couple of days in the field – coming up with a diatreme model for the breccias-hosted gold deposit and writing it up in a joint paper in "*Economic Geology*" in 1984.

Surprisingly, Dick hates flying ! He was at a dinner at our house in Lae (PNG) with a number of our geological friends around the table when the subject of his displeasure of flying came up. Well, knowing that he would be flying in a helicopter at Wau early the next morning, everyone naturally trotted out all their worst helicopter crash stories – which really unsettled Dick, as he had been in a helicopter crash the year before !

He has been one of the most regular contributors to the growing wealth of knowledge about mineral deposits of our generation, and he has written over 130 technical papers – including over 38 in "*Economic Geology*". In my mind, he is a modern day Waldemar Lindgren !

His 2010 overview paper on porphyry copper deposits Is the second-most cited paper in "*Economic Geology*", and in 2012 the SEG produced Special Publication No. 16 titled "*The Geology and Genesis of Major Copper Deposits and Districts of the World: A Tribute to Richard H. Sillitoe*".

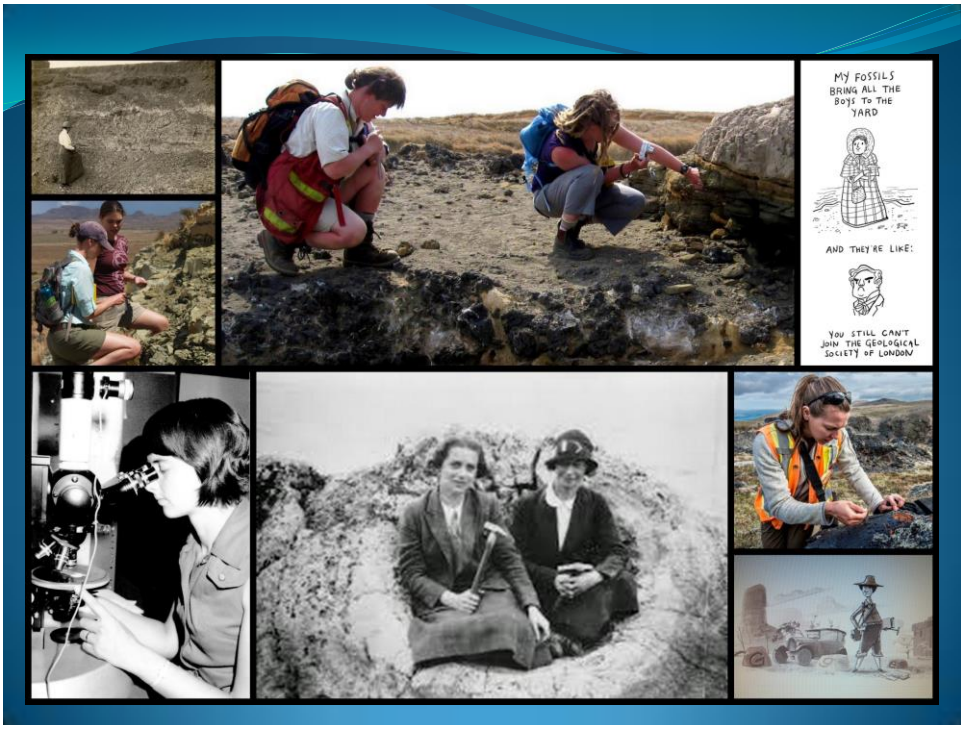
Dick is very generous with his time - he has spoken at nearly 100 international conferences, and has given over 50 lectures at universities and geological surveys around the world. In 1999 he was elected as the first President of the *Society of Economic Geologists* who was not American. Dick won the Society's *Waldemar Lindgren Award* in 1975, the Society's *Penrose Medal* in 2015, as well as winning many other international awards.

This is Dick in West Irian with a couple of his well-equipped field assistants ! He is a very modest, charming and generous man – the geologist we would all like to be **!**

I would encourage you all to see the online interviews with both David Lowell and Dick Sillitoe on the SEG website.

MORE LEGENDS ?

So we now come to the slot for my sixth and final Legend, and in this age of gender equality, I can hear many of you asking……."Come on Russell – where are your female Legends ?"

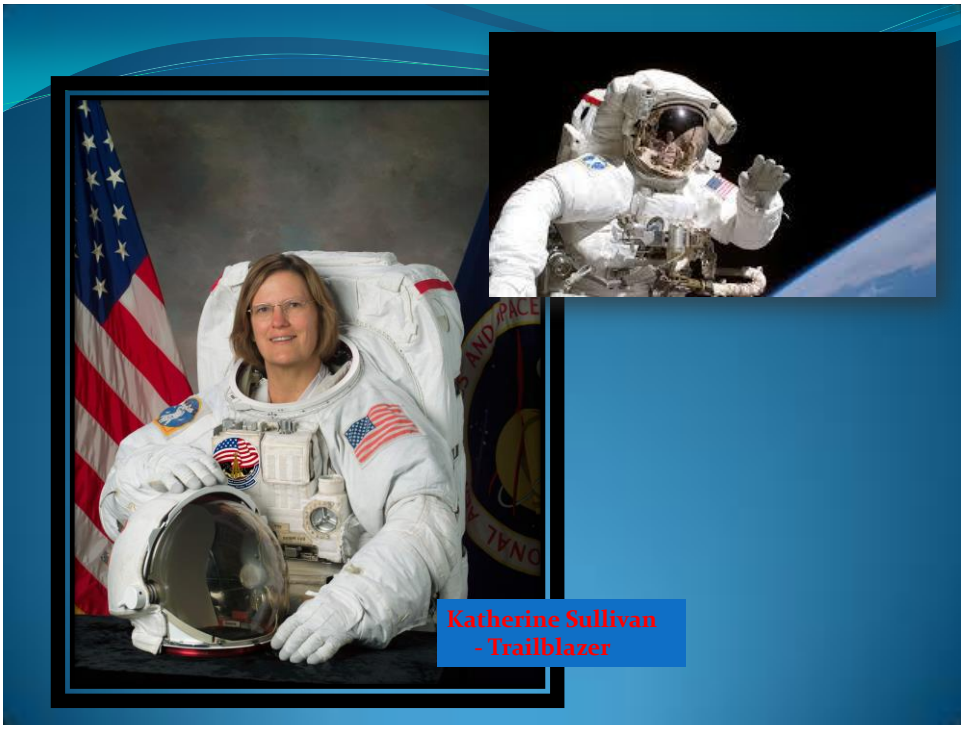


Women could not become members of the *Geological Society of London* until 1919 - 100 years after Mary Anning was discovering dinosaur fossils in the Jurassic cliffs of the coast of Dorset – because they were "*believed to lack the intellectual rigor to engage in scientific study*" !! What a bunch of old misogynists !!

Well……I have searched far and wide, and I regret to report that I have not found a single female standout Legend of Economic Geology ! I found lots of inspiring, high-achieving geologists of the fairer sex, but few in the field of Economic Geology. Those I did find were in the fields of volcanology, palaeontology, oceanography, space research, astrophysics, and petroleum geology – where they worship their female rock stars and write books to honour them ! Those who smashed the glass ceiling as the first to join some of the Geological Surveys were Florence Bascom (USGS 1896), Alice Wilson (Canadian Geological Survey 1909), and Diane Murphy who joined NSWGS in 1961 as an office geologist.

One of our own SMEDG Trailblazer Legends who is shown at her microscope in the photo below is with us tonight ! She is the wonderful Jane Barron – who joined the NSWGS in 1967 as their first "*Trailblazer field geologist*" – well done Jane !!!

Now the one Trailblazing pioneer who I did find whose achievements are literally “out of this world”, is this lady……



She is Katherine Sullivan - an American geologist who fulfilled her childhood dreams and went on three Space Shuttle missions, logging more than 500 hours in space. She was the first American woman to walk in space in 1984, three months after the first Russian woman astronaut – a huge achievement !

But predictably for such a ground-breaking female who was a high achiever, ultimately the misogynists derailed her career in public administration. In 2014 Barak Obama had appointed her as *Under Secretary of Commerce for Oceans and Atmosphere*, but she was unceremoniously dumped in 2017 by the ultimate misogynist Donald Trump !

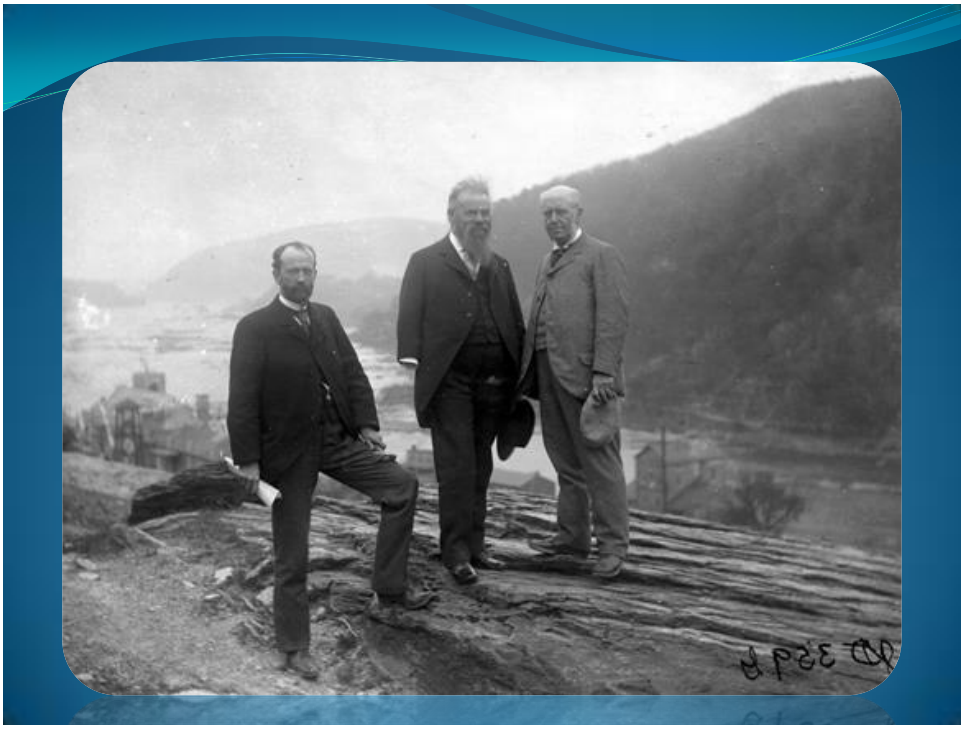
I would encourage everyone to support our own Trailblazers to help them achieve their potential, because I know that for them the sky is the limit !!

SO WHO IS MY FAVOURITE LEGEND ?

So after our long journey in the footsteps of giants, I'd like to tell you which of these rock stars is my favourite Legend. Which one impressed me the most ?

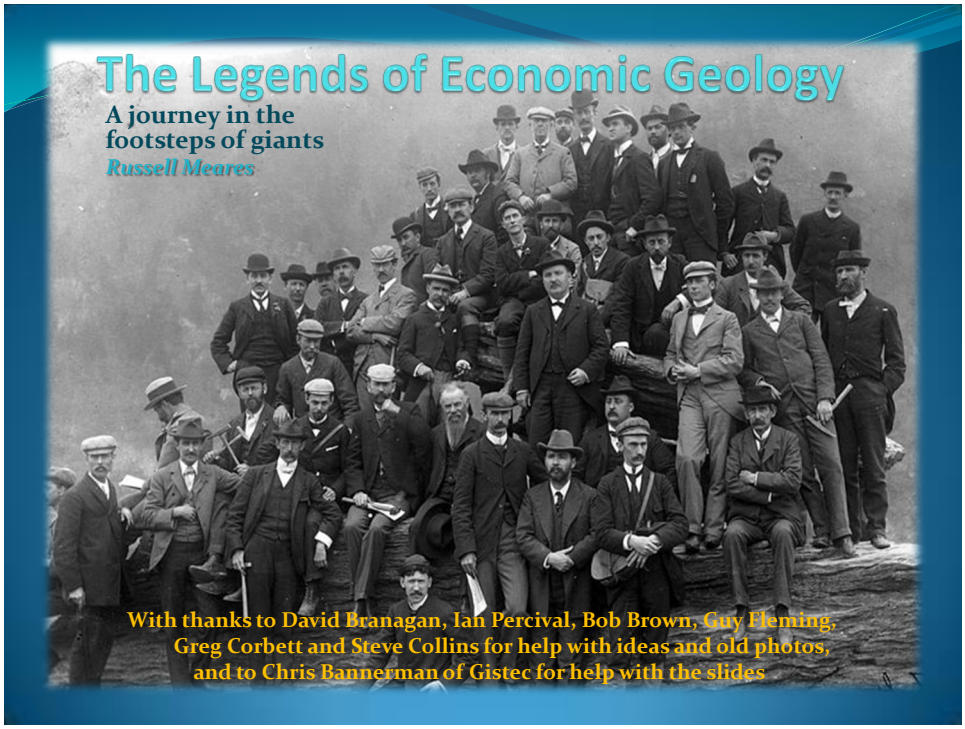
Well, firstly let me share with you a secret about the two bad habits we geologists have when someone hands us a rock and they say……."*Russell – what do you think this rock is* ?"

The first thing we do is lick it ! Then we have a good look with our hand lens, and after what seems like an eternity to some onlookers we say……."*On the one hand it could be granite, but on the other hand it could be an arkose*" ! Well folks…….my favourite Legend never had that problem, because my favourite Legend had only ONE ARM !!!



John Wesley Powell never said ……. "*On the one hand – on the other hand*" !! …….because he lost his right arm when he was hit by a cannonball in the Battle of Shiloh in the American Civil War – before he twice went down the Grand Canyon, and before he became the 2nd Director of the USGS. Not bad achievements for a man with only one arm who stood 5' 6" tall !!

And on Powell's left in the above photo is Archibald Geike. Both Powell and Geike are wearing the same clothes and holding the same hats in both photos – which were presumably taken on the GSA field trip on the same day.



As well as those people who have helped with this presentation listed on the photo above, I'd like to thank my beautiful wife (Win) for her support, understanding and incredible patience while I burnt the midnight oil researching and creating this talk !

So in conclusion, the common strengths which my chosen Legends share are an inquiring mind, a self-belief tempered by great humility, and a "can do" approach to everything they did.

And finally, I hope that each and every one of you can find a Crowded Hour in your life !

Thank you !