U3A
Contributions to Geology

Lecture 4 The Australians

Introduction

- Study of geology in Australia began later than in Europe
- Australians have made significant contributions to modern advances in the science
- study of geology in Australia took a quantum leap during the 19th century gold rushes
- in late 19th to early 20th century the Victorian Geological Survey was considered amongst the best Geological Surveys in the world

Reverend William Branwhite Clarke (1798 – 1878)

Geologist, poet, amateur meteorologist and Anglican clergyman,

Considered "the father of Australian geology"

William Branwhite Clarke

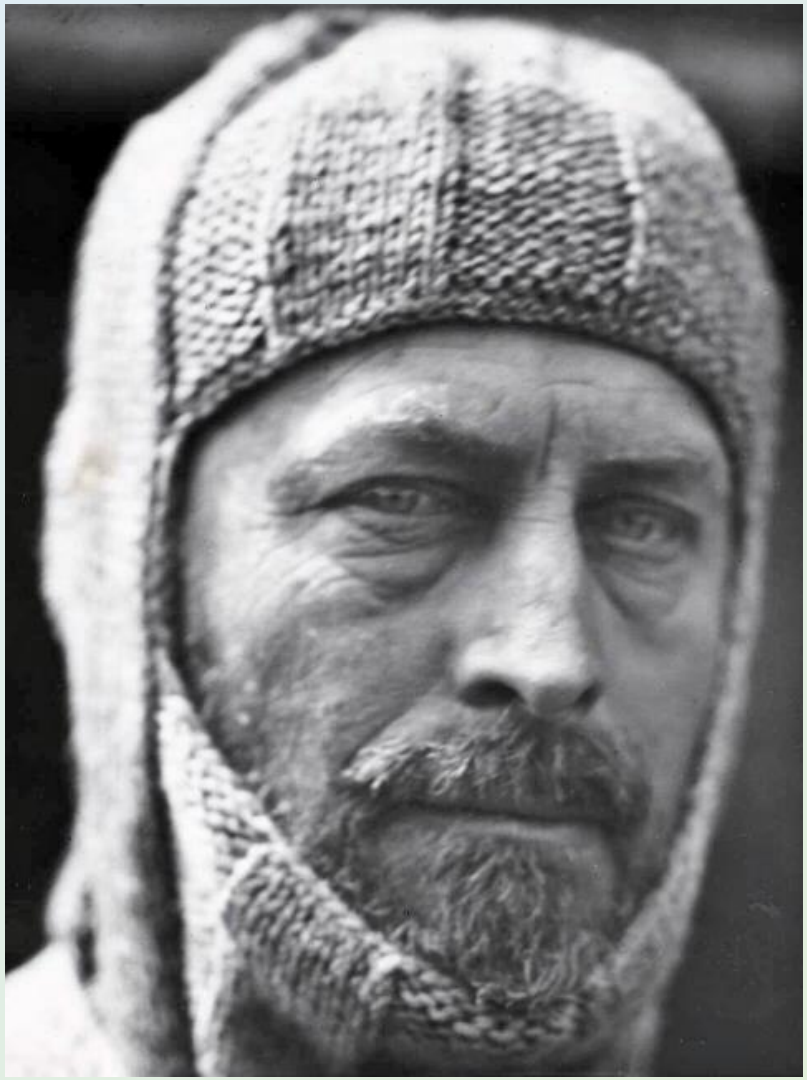
- Graduated with MA from Jesus College, Cambridge University in 1824
- appointed vicar of St Mary's church in Dorset in 1832
- interest in geology came from lectures given by Adam Sedgwick
- emigrated to Australia in 1839 to evaluate geology
- after short stint as headmaster of Kings School, Paramatta, pursued interest in geology → collected large quantity of fossils and rocks
- discovered gold in Bathurst district 7 years before Edward Hargreaves
- assessed Au potential of northern Tasmania for Tasmanian government
- most important contribution to Australian geology → determination of age of NSW coal deposits

Willian Branwhite Clarke

- Published reports, books, maps and some 80 scientific papers
- awarded Murchison medal of the Geological Society of London in 1877 for his work on NSW coal deposits
- contributed twenty articles on meteorology to Sydney Morning Herald and encouraged setting up of weather observation network
- his geological maps formed the basis of the first geological sketch map of NSW

Sir Douglas Mawson (1882 – 1958)

Geologist and Antarctic explorer



Douglas Mawson

- Born in Yorkshire, England → moved to Australia as a child in 1884
- studied mining engineering at Sydney University graduated BE (1902)
- returned to study geology and chemistry → obtained BSc (1904)
- undertook geological survey of New Hebrides (Vanuatu) in 1904
- under influence of Archibald Liversidge became a pioneer on aspects of geology and geochemistry → wrote papers on radioactive minerals
- appointed lecturer in mineralogy and petrology at University of Adelaide, 1905 → took up interest in glaciology and U mineralisation
- member of Shackleton's 1907-9 Nimrod Antarctic expedition and the Australasian Antarctic expedition 1911-14

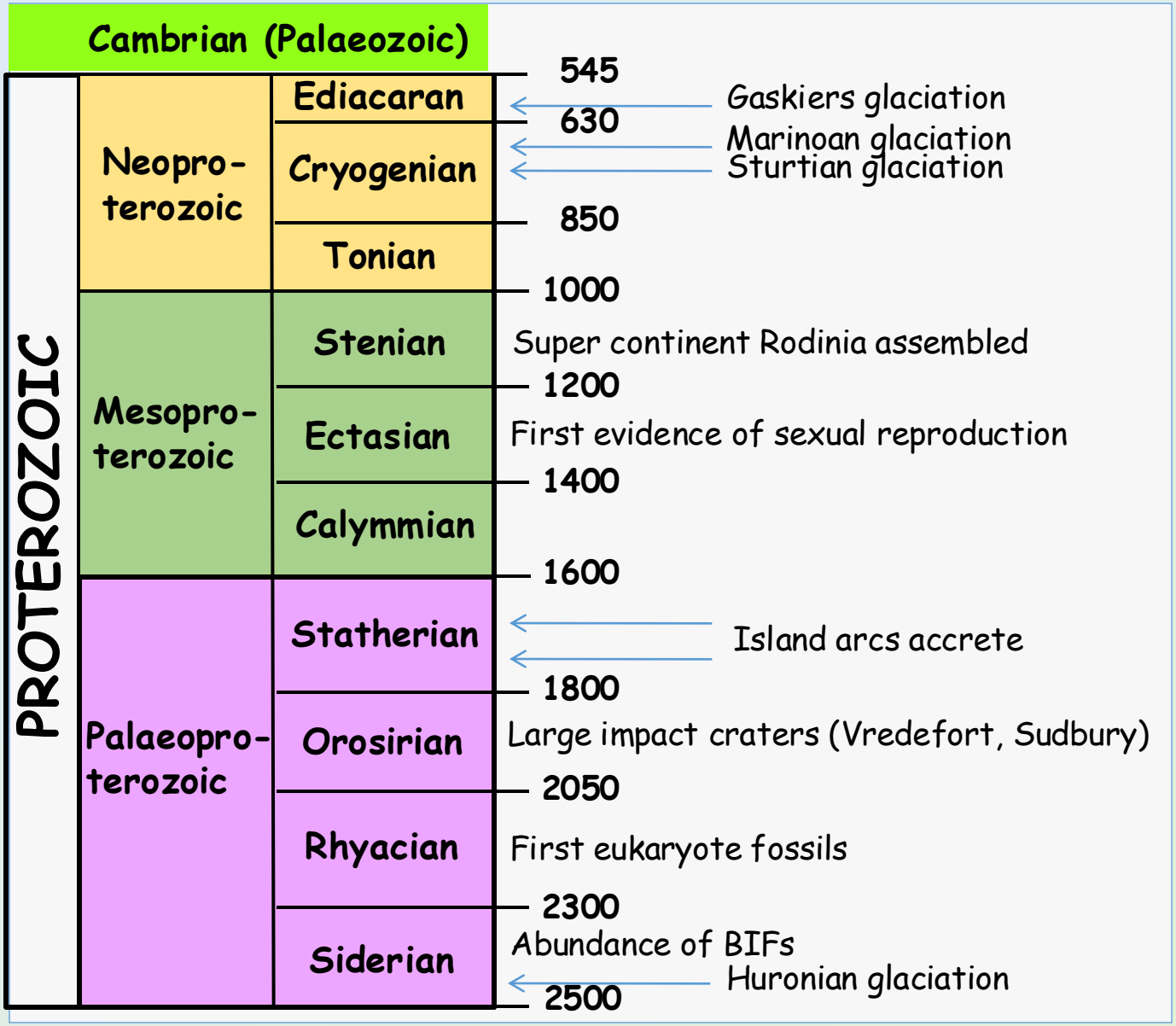
Douglas Mawson

- Conducted extensive research of the Barrier Range from the Flinders Ranges to Broken Hill over 40years (glaciation, metamorphism)
- identified two groups of rocks → Late Palaeoproterozoic group he named the Willyama Complex; Neoproterozoic series called the Adelaidean Supergroup
- delineated Neoproterozoic glacial sediments over distance of 1500km
- proved that glacial conditions persisted through much of the Neoproterozoic period → evidence for "Snowball Earth theory"
- also interested in geochemistry of igneous, metamorphic rocks, origin of carbonaceous sediments and rare minerals

Douglas Mawson

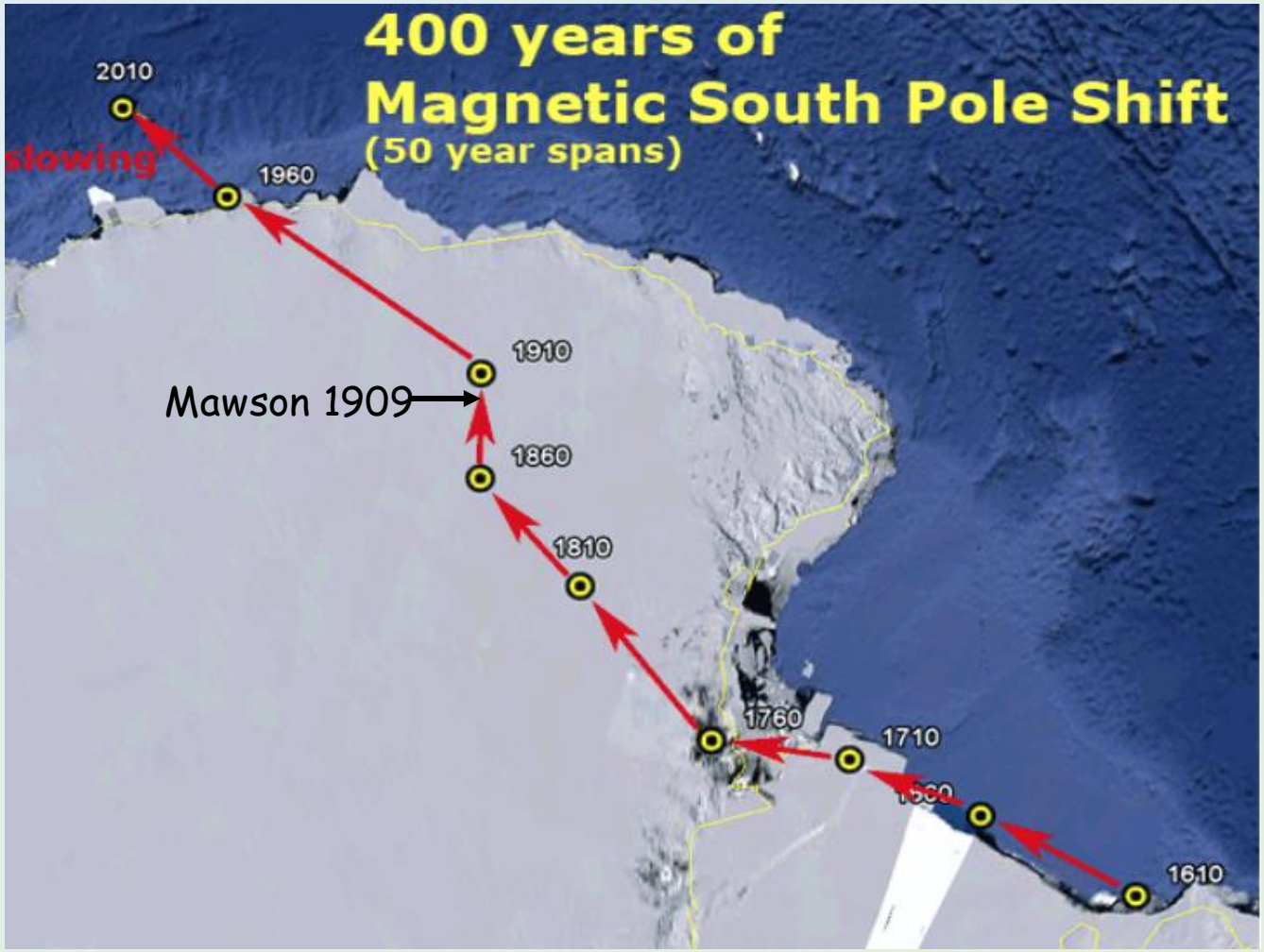
- appointed Professor of geology and mineralogy at Adelaide University in 1921
- instrumental in setting up of the Mawson Antarctic station
- a number of biographies written about Mawson, ranging from the nice Mawson (written by Lincoln Hall) to the not so nice Mawson (written by David Day)
- a more objective biography was written by Philip Ayres
- Mawson's life was not faultless, however, his contribution to the understanding of South Australian geology → monumental

Proterozoic Eon



South magnetic polar wander

The South magnetic pole is the wandering point on the Earth's Southern Hemisphere where geomagnetic lines are vertical



South magnetic pole 1909

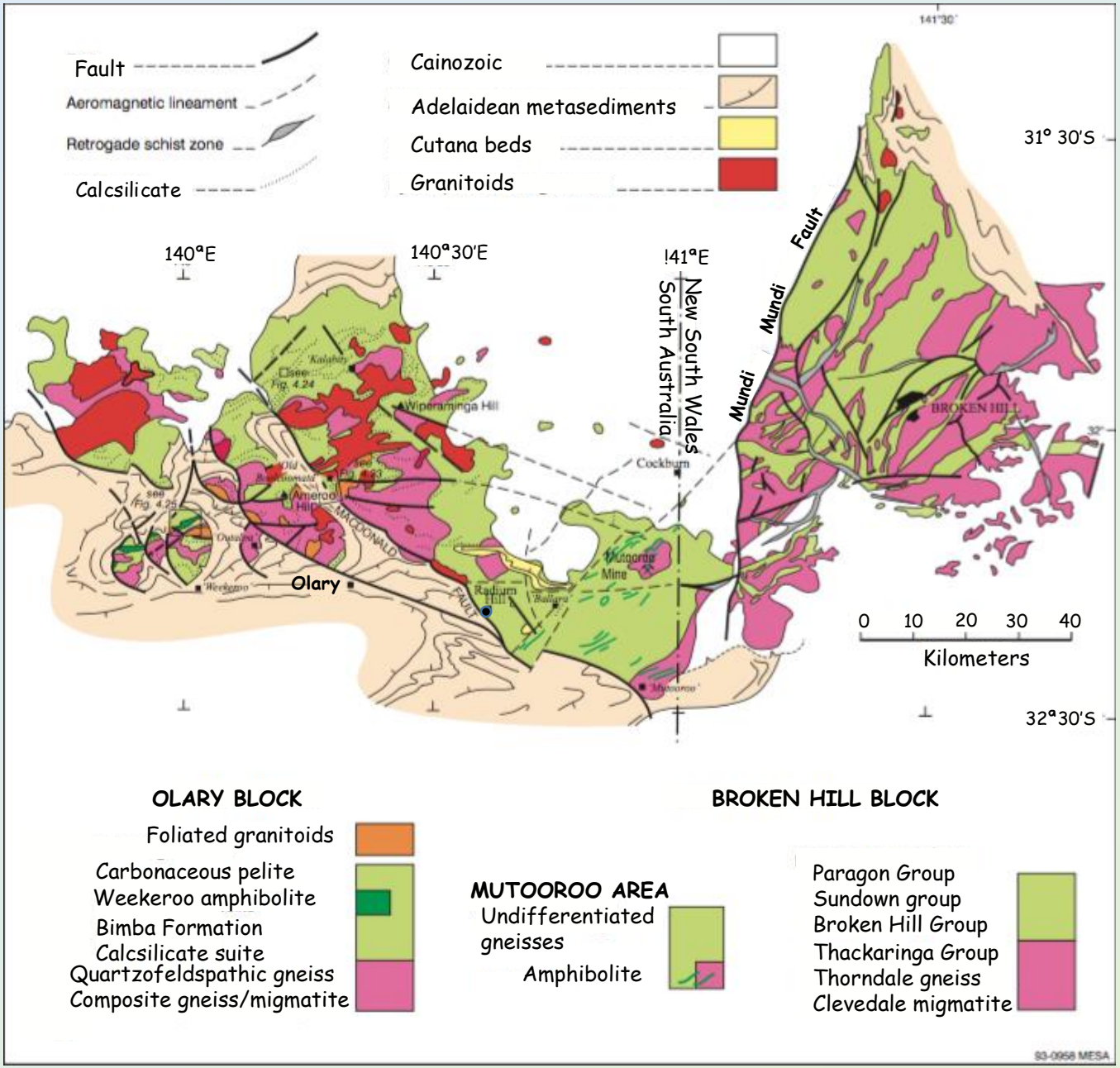
Douglas Mawson, Edgeworth David and Alistair MacKay were the first to reach the vicinity of the South Magnetic Pole in 1909

From left: Alistair MacKay, Edgeworth David and Douglas Mawson South Magnetic Pole 1909

Willyama complex

- The Palaeo-Mesoproterozoic Willyama complex extends from the Olary province in SA into NSW where it hosts Ag-Pb-Zn deposits
- the Crocker Well and Radium Hill uranium deposits are contained within shears in the complex
- the complex contains highly deformed regional metamorphic rocks
- rocks in the complex comprises schists, gneisses, felsic and mafic intrusives and extrusives and highly mineralised sulphide ore deposits

Willyama Complex



Germaine Joplin (1903 – 1989)

Geologist known for her studies of petrography of Australian igneous and metamorphic rocks

Germaine Joplin

- Trained initially as a nurse → enrolled at Sydney University
- graduated with BSc from Sydney University, 1930 → awarded scholarship to Cambridge University
- obtained PhD from Newnham College, Cambridge University, 1936
- from 1941-45 conducted a survey of the Cooma Metamorphic Belt
- gained permanent research position at ANU, Canberra in 1952
- compiled geochemical data on Australian rocks → published:

  "A Petrography of Australian Metamorphic rocks"

  "A petrography of Australian igneous rocks" 1964

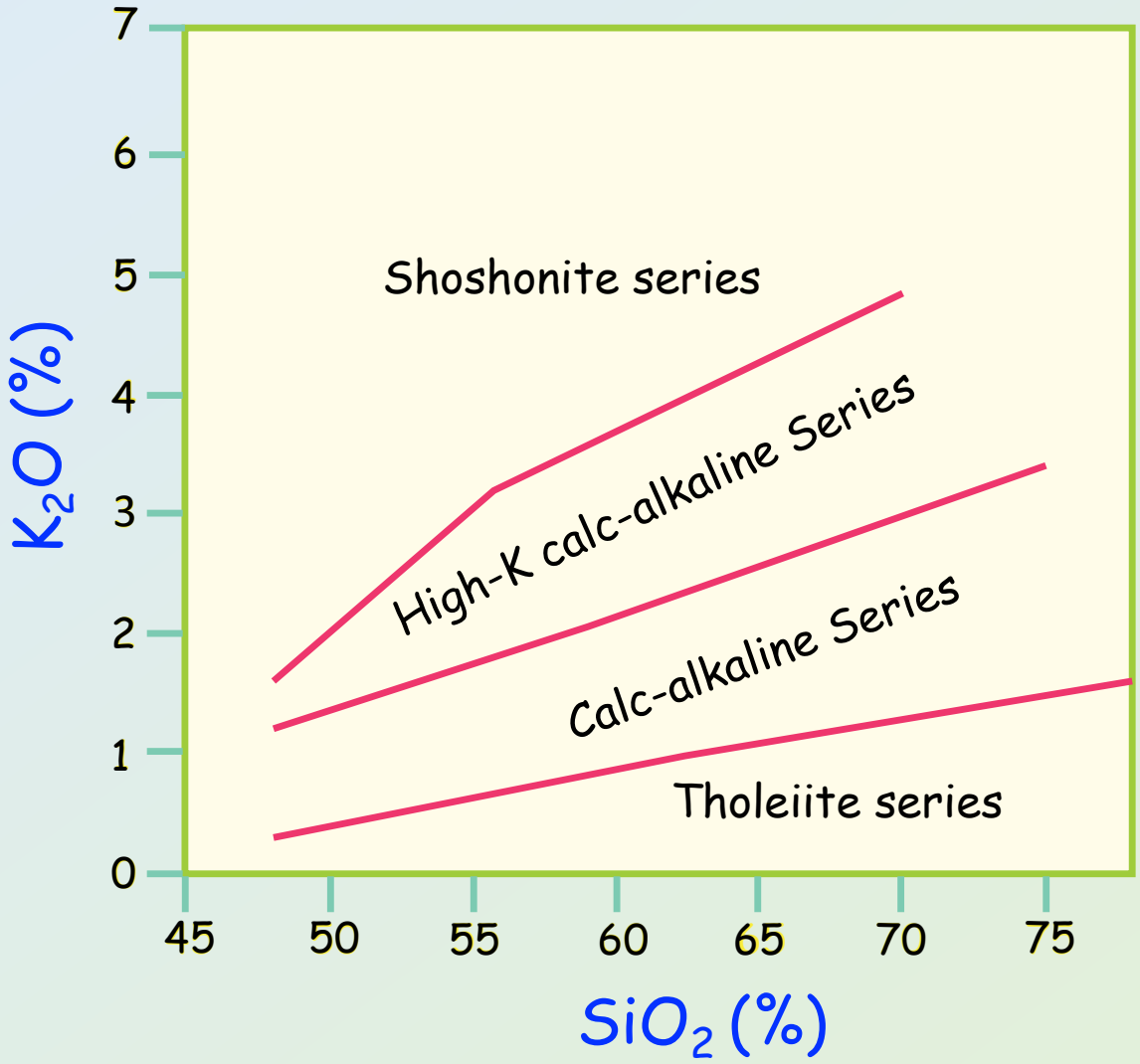
  "Finding the age of rocks" 1972
- introduced the concept of the shoshonite suite of rocks

Shoshonites

- Igneous rocks associated with calc-alkaline, island arc volcanism
- K-rich, younger and occur above deeper parts of Benioff zone
- usually felsic lavas
- shoshonites have following chemical characteristics:

    1. Near saturated with silica
    2. low Fe
    3. high total alkali content ($Na_2O + K_2O$) >5%)
    4. high K_2O/Na_2O
    5. enrichment in P, Rb, Sr, Ba, Pb, LREE
    6. low TiO_2
    7. high but variable Al_2O_3
    8. high Fe_2O_3/FeO

Subdivision of subalkalic rocks



Extracts from "A Petrography of Australian Igneous Rocks"

The *syenite* is a coarse-grained rock near the centre of the mass, where it forms huge tors. Finer-grained types occur near the margin and some of these are slightly porphyritic. The rock consists of large interlocking grains of microperthite, subidiomorphic prisms of hornblende, commonly altered to actinolite and magnetite (Fig. 13A), a little biotite, a little diopsidic augite and commonly irregular grains of quartz. Some types may contain oligoclase. Zircon is abundant for an accessory mineral and may form relatively large crystals. Other accessories are apatite, magnetite and sphene (see Table XV).

The *bostonites* consist of small tabular crystals of anorthoclase in a trachytic, slightly orthophyric groundmass of anorthoclase laths and a little interstitial quartz.

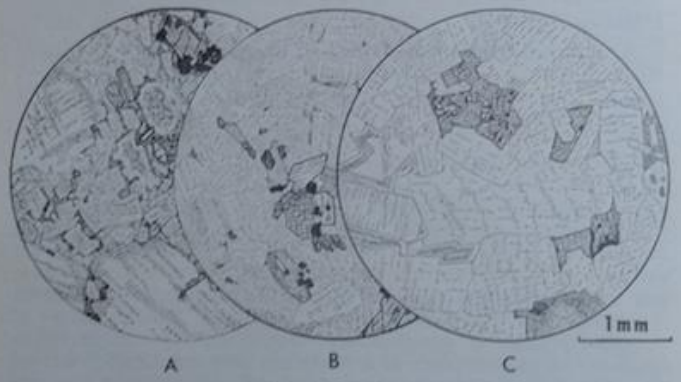


Fig. 12. Syenites

A. Porphyritic soda syenite, Bushranger's Hill, near Dubbo, N.S.W., showing large subidiomorphic tabular crystals of anorthoclase in a medium-grained hypidiomorphic granular groundmass consisting of soda sanidine and oligoclase, prisms of aegirine-augite and accessory magnetite and apatite.

B. Microsyenite, Mt Gibraltar, Bowral, N.S.W. Medium-grained hypidiomorphic granular rock consisting of tabular crystals of potash feldspar and prismatic crystals of aegirine-augite much altered to carbonates. The pyroxene occurs in small clots and is associated with iron ores, sphene and a trace of alkali amphibole.

C. Syenite pegmatite, Mt Gibraltar, Bowral, N.S.W. Large tabular subidiomorphic crystals of sanidine are partly wrapped by large crystals of bright green arfvedsonite, in places partly altered to carbonates, and in places enclosing rounded crystals of pyroxene. Interstices are filled with quartz with a border of chalcedony or with carbonates alone. Large crystals of sphene occur, and apatite is accessory.

TABLE XXIII

SHOSHONITIC ROCKS, EXCLUDING ROCKS FROM MOUNT DROMEDARY

	1	2	3	4	5	6	7
SiO_2	51.11	51.32	53.90	55.68	58.82	61.25	63.10
Al_2O_3	17.70	18.82	15.32	16.08	14.78	18.59	17.11
Fe_2O_3	3.99	4.50	3.60	3.55	3.90	1.58	1.04
FeO	5.13	2.97	5.13	3.85	3.24	2.18	3.02
MgO	3.43	3.58	2.41	2.92	2.26	0.58	1.15
CaO	6.51	6.42	7.30	6.18	3.09	4.05	3.65
Na_2O	3.97	3.97	3.73	3.55	4.67	4.30	3.94
K_2O	3.25	3.31	3.44	3.72	4.70	4.06	4.64
H_2O+	2.41	2.89	0.97	0.69	1.36	0.42	0.42
H_2O-	0.52	0.87	0.74	1.63	0.81	0.60	0.55
CO_2	0.01	0.10	0.03	0.28	0.05	abs.	0.24
TiO_2	1.34	0.56	2.86	0.91	1.78	1.28	0.82
P_2O_5	0.65	0.42	0.55	0.71	0.58	0.61	0.30
MnO	0.32	0.23	0.36	0.21	0.23	0.42	0.12
BaO	0.07	0.22	0.06	0.12	0.12	—	—
NiO	0.02	0.01	0.02	0.01	0.02	—	—
CuO	—	0.02	0.01	—	—	—	—
V_2O_3	0.05	0.04	0.02	—	0.02	—	—
Cl	0.01	tr.	0.02	—	—	—	—
F	—	—	—	0.13	—	—	—
				100.22			
Less O = F				0.05			
	100.49	100.25	100.47	100.17	100.43	99.92	100.10

1. Porphyritic monzonite, Milton, N.S.W. Anal. H. P. White.
2. Minnamurra "shoshonite", Gerringong Volcanics, South Coast, N.S.W. Anal. H. P. White.
3. Monzonite porphyry, Milton, N.S.W. Anal. H. P. White.
4. Bumbo "shoshonite", Gerringong Volcanics, South Coast, N.S.W. Anal. J. H. Pyle.
5. Cambewarra latite, Gerringong Volcanics, South Coast, N.S.W. Anal. H. P. White.
6. Syenite porphyry (banatite), Port Cygnet, Tasmania. Anal. A. B. Edwards.
7. Syenite porphyry (banatite), Port Cygnet, Tasmania. Anal. A. B. Edwards.

poikilitic crystals of feldspar and of biotite may measure up to 20 mm. in diameter.

The monzonite contains potash feldspar, plagioclase, augite, biotite, hornblende, apatite, sphene and iron ores. Potash feldspar occurs in large irregular grains that envelop all the other minerals to give the characteristic monzonitic fabric. This feldspar contains a vermi-

Dorothy Hill (1907 - 1997)

Australian geologist and palaeontologist whose work on fossil corals and Archaeocyathids is world renowned

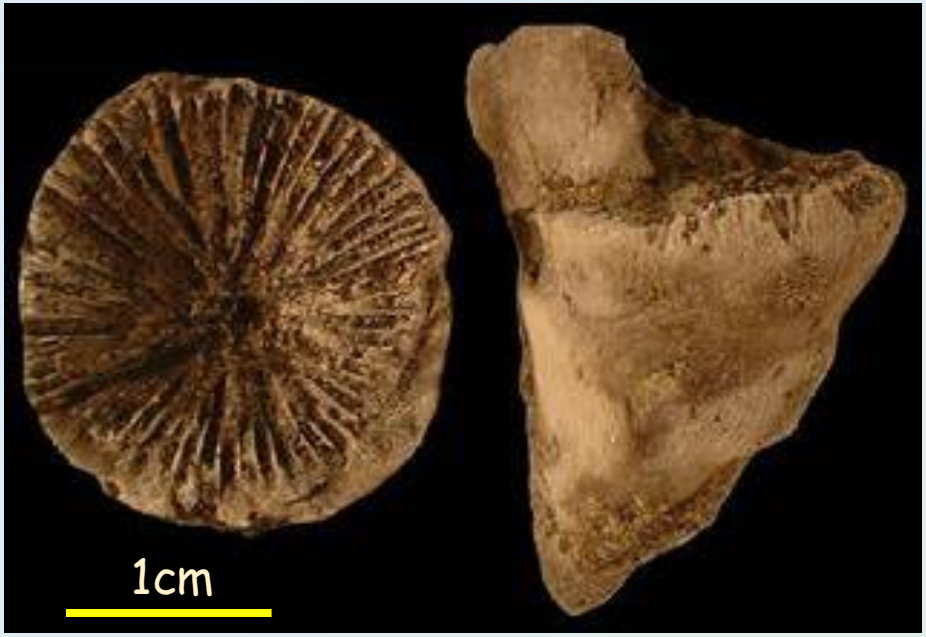
Dorothy Hill

- Outstanding athlete and adventurer, state hockey player and pilot
- graduated with first class honours in geology in 1928 from University of Queensland → first woman to win University Gold medal
- started MSc studying limestone-hosted corals in Brisbane valley → before completion → awarded scholarship to Cambridge University
- studied Carboniferous corals in Scotland → returned to Australia 1937
- defined structural details of extinct corals → established terminology for rugose corals
- appointed lecturer in geology University of Queensland, 1937
- wrote extensively on corals and their use in stratigraphy

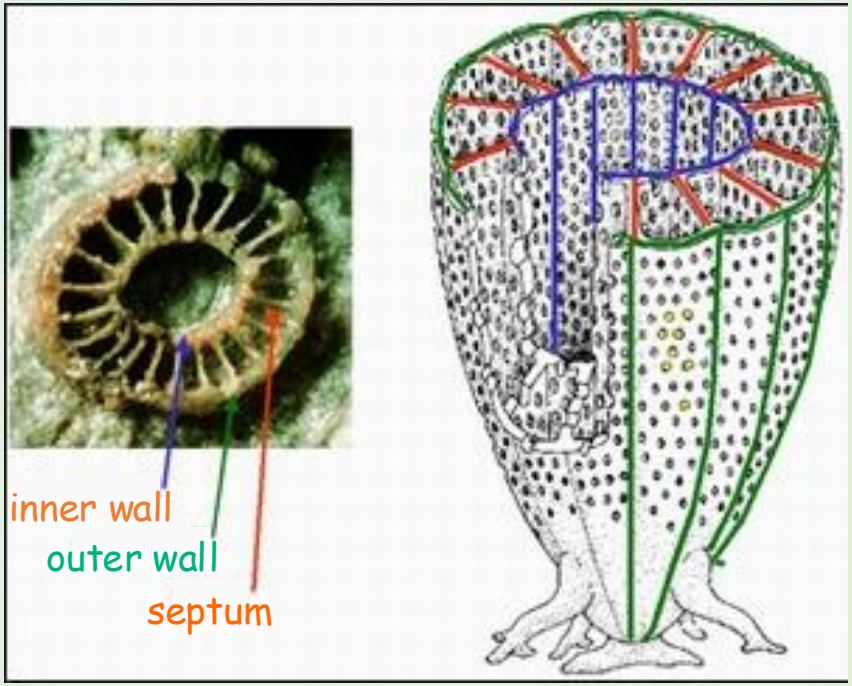
Dorothy Hill

- placed into order of relative age, Australian fossil coral faunas → application to stratigraphy, correlation of Australian limestone sequences
- studied and classified Archaeocyathids
- won universal recognition for studies on extinct corals and Archaeocyatha
- published treatises on Coelenterata (Cnidaria) and Archaeocyatha
- served as secretary of Great Barrier Reef committee → helped administer research station on Heron Island
- received innumerable honors for her contributions to science

Rugose coral and Archaeocyathid



Solitary rugose coral



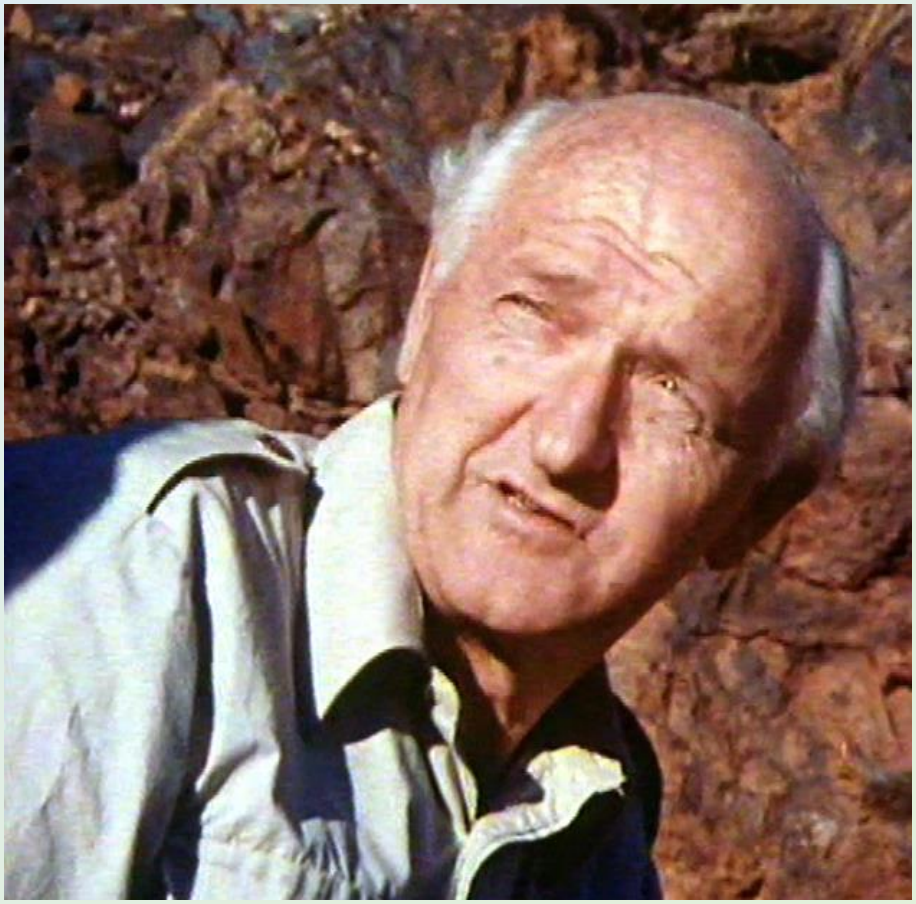
Archaeocyathid

Dorothy Hill honours

- First female fellow of the Academy of Science
- First Australian woman to be a fellow of the Royal Society of London
- First president of an international association for the study of Cnidaria and Porifera
- Described as the most outstanding graduate in first 75 years of the University of Qld
- First Australian female professor
- Named after her: scholarship at University of Qld., school campus, Research vessel on Barrier Reef, state electorate, street in 2018 Commonwealth Games village, medals awarded by Academy of Science and Geological Society of Australia

Reg Sprigg (1919 -1994)

Australian geologist and conservationist famous for his discovery of Ediacaran fossil fauna (oldest multicellular fossils), founder of South Australian oil and gas industry



Reg Sprigg

- Born on Yorke Peninsular, South Australia in 1919
- developed an interest in geology whilst at school (avid fossil collector)
- enrolled at Adelaide University in 1937
- described by Mawson as his "best ever student"
- graduated with MSc from Adelaide University in 1942 (Douglas Mawson was his mentor)
- recruited by Soils Division of CSIRO to explore for uranium around Mt Painter in the Radium Hill U field

Reg Sprigg

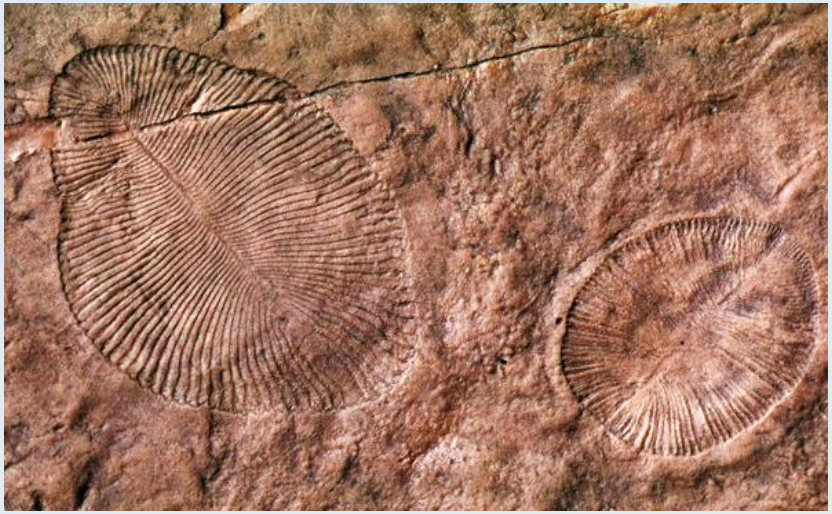
- During 1946 visited Ediacra Hills to investigate re-opening of old mines → discovered unusual fossils
- discovery of Ediacaran fauna in the hills → eventually led to definition of Ediacaran Period
- formed his own exploration company (Geosurveys) in 1952 exploring for Ni and U in NW South Australia
- aided in establishing SANTOS that discovered gas in Cooper Basin including Moomba gas fields
- learned scuba diving to explore underwater geology around SA discovered deep submarine canyons south off Kangaroo Island
- purchased Arkaroola pastoral lease in Flinders Ranges (1968)

Ediacaran Fauna

- Oldest known, multicellular, soft-bodied organisms
- discovered in Flinders Ranges by Reg Sprigg in 1946
- nature of Ediacaran fauna highly controversial. What are they? To what phyla do they belong?
  - interpreted as jellyfish, sea pens, segmented worms, primitive arthropods
  - found on all continents except Antarctica
  - Age 640-545 million years

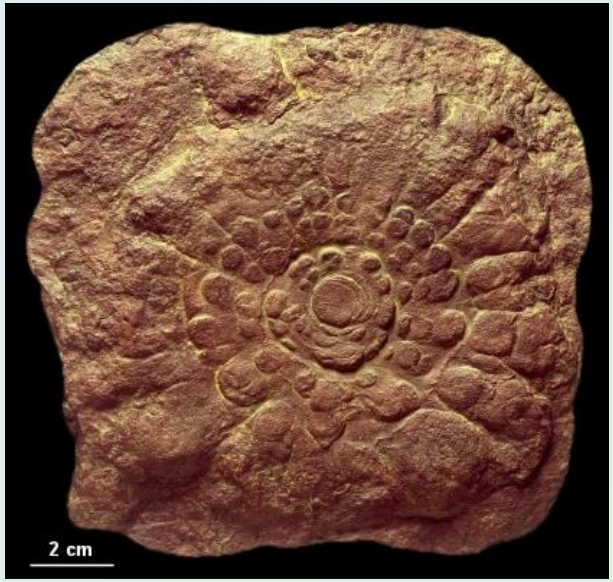
Cyclomedusa

Ediacaran fossils



Genus *Dickinsonia*

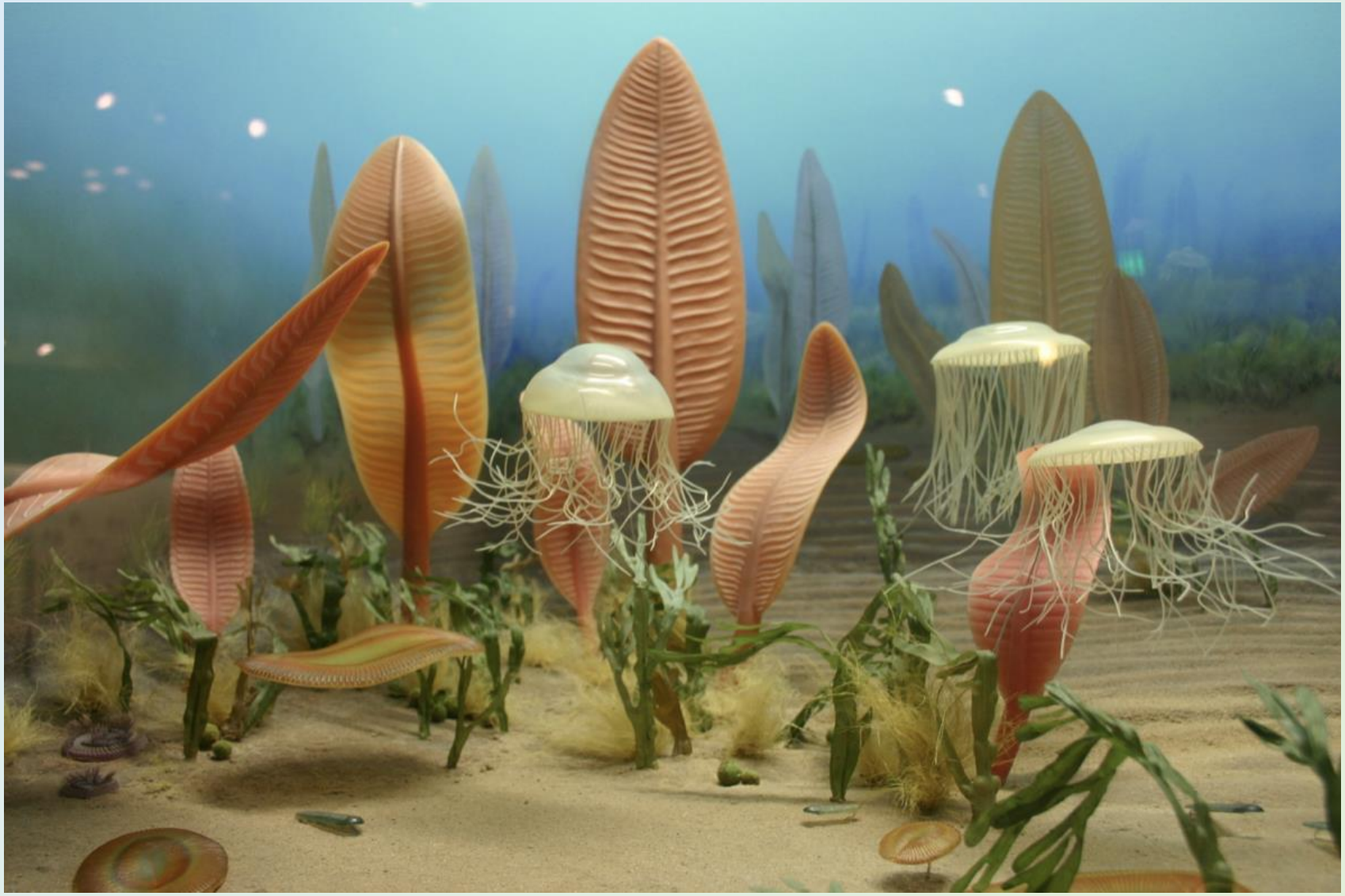
Sea pen



Mawsonites sprigii

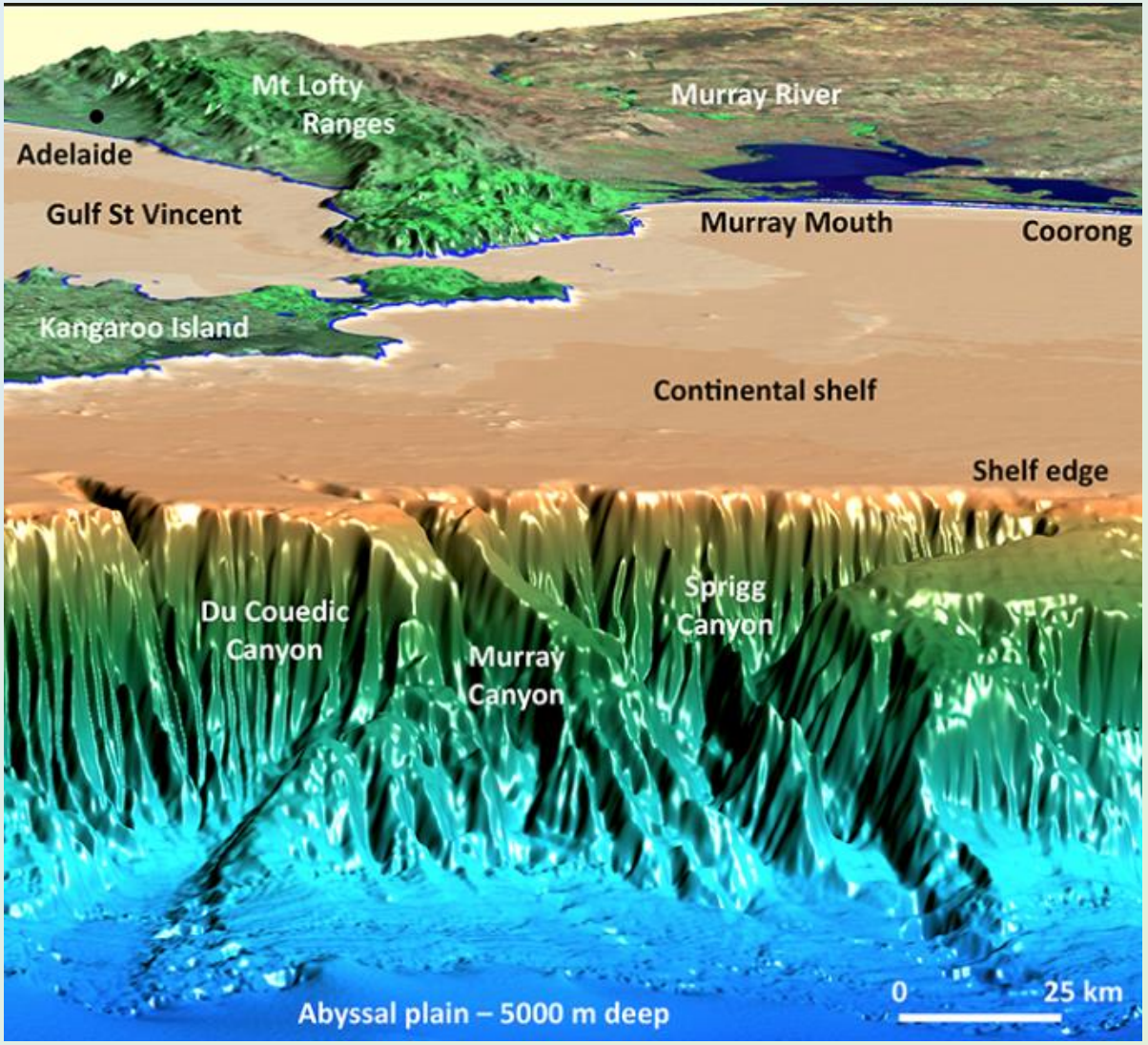
Spriggina floundersi

Ediacaran diorama

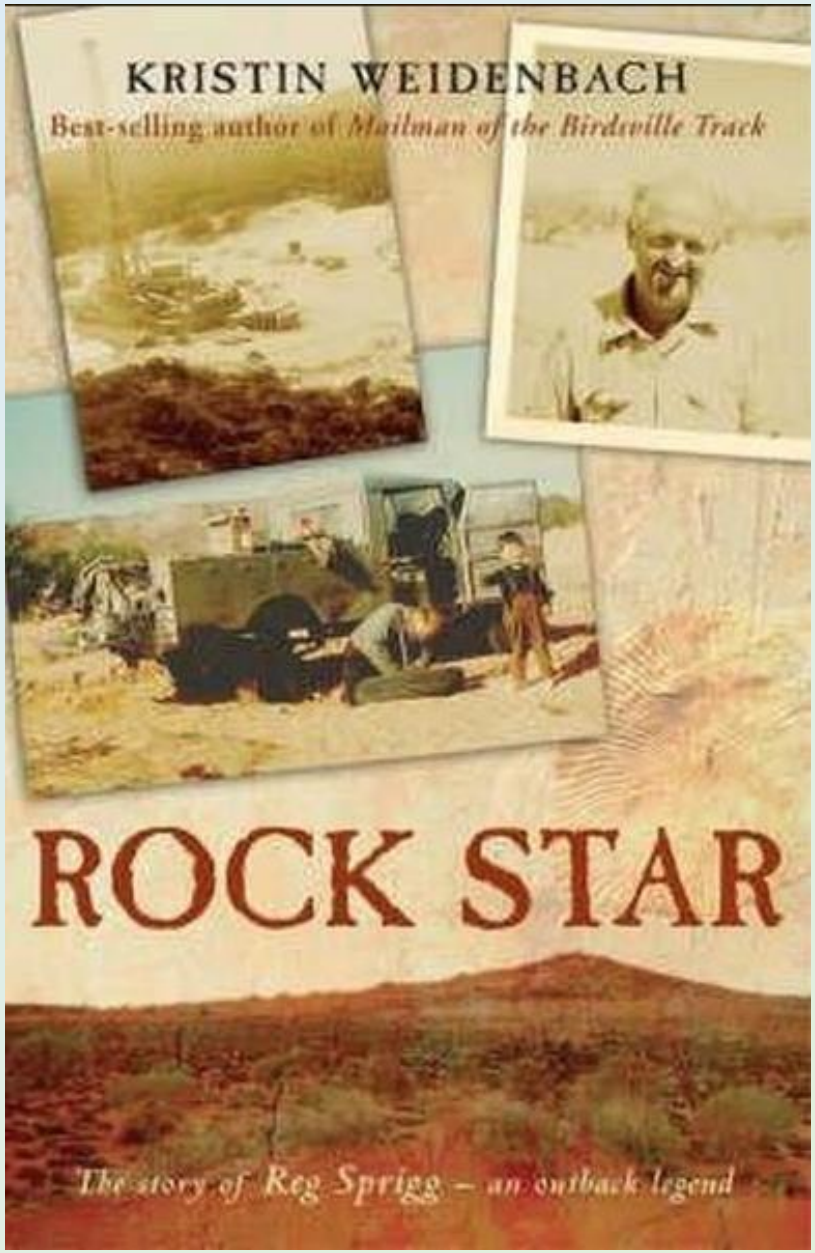


Submarine canyons off the S Aust. coast

Eroded by ancient Murray river during last ice age



"Rock Star" the story of Reg Sprigg



Alfred Ted Ringwood (1930 – 1993)

Outstanding geologist and experimental petrologist who contributed much knowledge on the composition of the Earth's mantle

Ted Ringwood

- Graduated with a MSc in geology from Melbourne University → mapping and petrology study of the Snowy River Volcanics, NE Vic
- during his MSc mapping, he collected galena from an abandoned mine in E Victoria and sold it as feedstock for the Melbourne shot tower
- completed PhD at Melbourne University studying the application of geochemistry in understanding the structure of the Earth's mantle
- after two year post doctoral fellowship at Harvard → assumed research position at ANU, Canberra
- published in Nature → "The olivine to spinel transformation in the Earth's mantle"

Ted Ringwood

- Developed interest in the chemical composition and evolution of the solar system with emphasis on different types of meteorites
- supported controversial Synroc project for storing uranium waste
- identified that the Earth's upper mantle was of peridotite composition rather than basaltic that was popular at the time
- director of the Research School of Earth Sciences at ANU from 1978 to 1983
- published two books → "The composition and petrology of the Earth's mantle" (1975) and "The origin of the Earth and the moon" (1979) as well as over 300 scientific papers

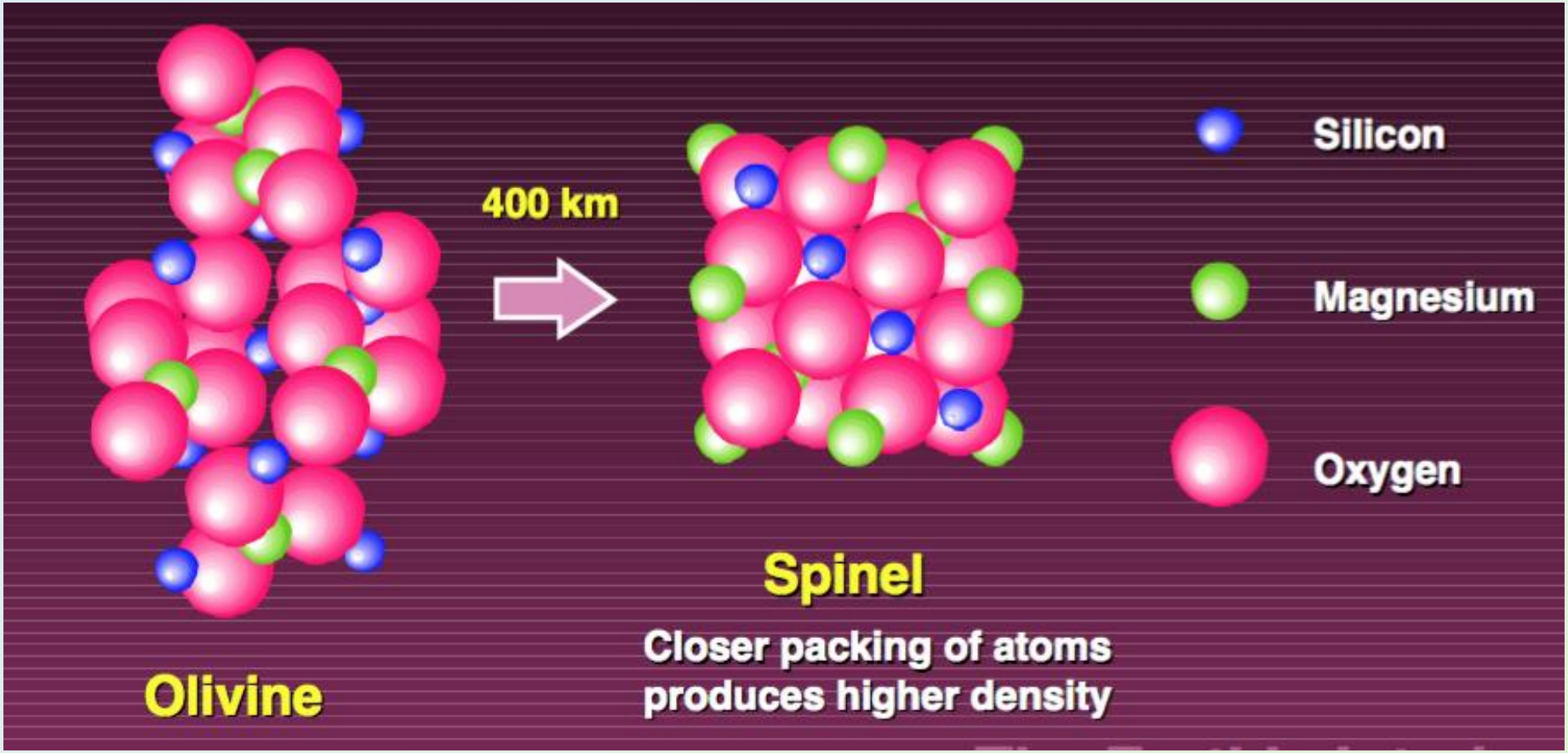
Phase changes in the mantle

- Ringwood proposed that upper and lower Earth's mantle have similar chemical compositions
- recognised phase transformations in mantle occur due to change in pressure rather than chemistry → established nature of transition zone
- changes in velocity are probably due to polymorphic structural changes in minerals, especially olivine → accompanied by increase in density and seismic velocity
- high temperature and pressure lab experiments can reproduce these phase changes → increase in density and seismic velocity
- not possible to simulate pressure conditions in lower mantle

Olivine phase changes

Low pressure polymorph

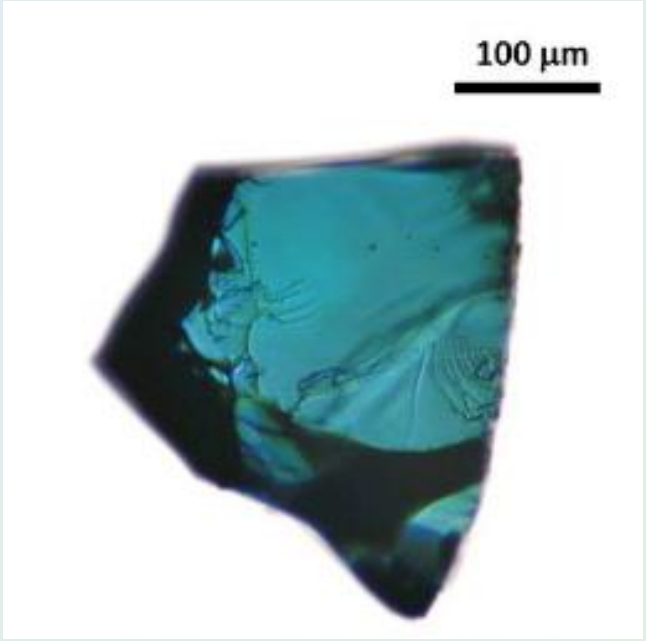
High pressure polymorph



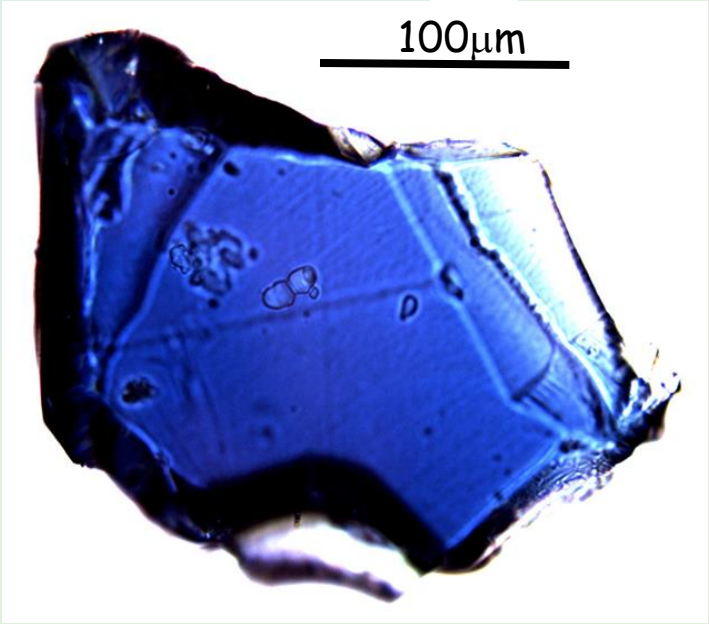
Olivine phase changes

Important changes in seismic velocity occur at pressures equivalent to 410 and 660km depths where these discontinuities occur

- at ~410km → olivine changes to a spinel polymorph → Wadsleyite
- at ~520km → Wadsleyite transforms into Ringwoodite
- at ~660km → Ringwoodite is transformed into even denser perovskite



Synthetic Wadsleyite

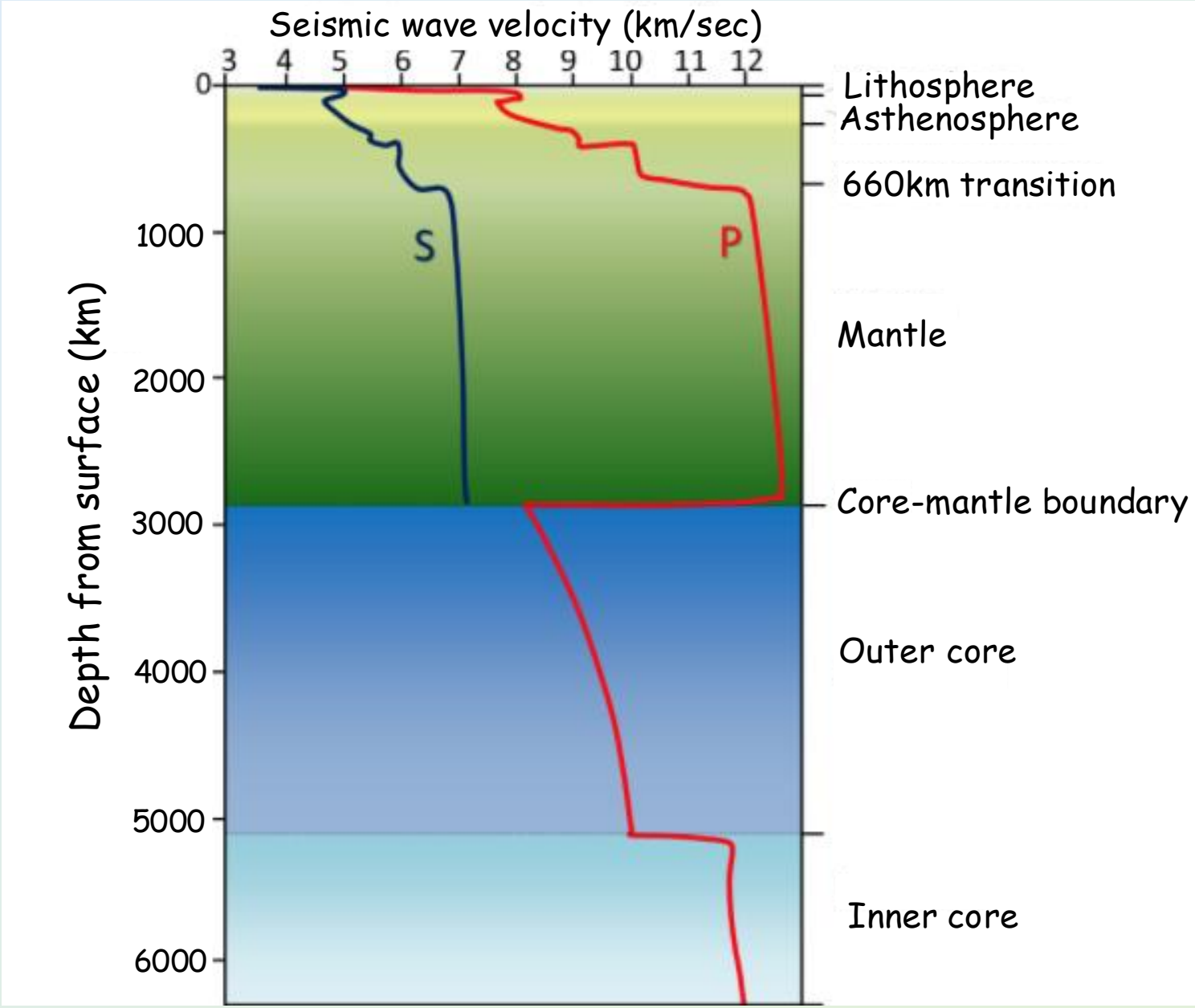


Synthetic Ringwoodite

Seismic discontinuities

- At certain levels in the Earth's interior seismic velocities change abruptly → seismic discontinuities
- the core-mantle boundary is a major example of a seismic discontinuity i.e. a rapid change in seismic velocity within Earth
- other seismic discontinuities occur at the outer core-inner core boundary and also in the upper mantle
- within the upper mantle, velocity changes are caused by phase changes → denser polymorphs

Seismic wave velocities in the Earth's interior



Alan White (1931-2009) and Bruce Chappell (1936-2012)

Known throughout the geological world for their research on granites

Alan White and Bruce Chappell

Allan White

- BSc (Hons) Adelaide University in 1951 (Mawson's last Honours student)
- Completed PhD at Kings College, London in 1956
- Lecturer at Otago University, NZ 1957-60
- Senior lecturer ANU, Canberra 1960-70
- Appointed foundation Chair of Geology La Trobe University 1971

Bruce Chappell

- MSc New England University 1960
- Lecturer ANU 1960-1966 while researching his PhD (1971)
- Professor and researcher ANU
- internationally renowned geochemical analyst of rocks

S and I type granites

- White and Chappell studied granites in SE Australia → recognised two contrasting types
- the two groups of granites owe their differences to derivation from the partial melting of igneous and sedimentary source rocks
- the two contrasting granite types are called S-type granites and I-type granites and the classification scheme is universally recognised
- proposed chemical variations within granite suites → result from variations in amount of residual solid material from partially melted source → Restite model
- only fundamentally new processes dealing with evolution of igneous rocks since Bowen (1928)

S and I type granites

Parameter	S-type	I-type
SiO_2	66-75%	56-75%
K_2O/Na_2O	high	low
CaO	low	high
$Al_2O_3/Na_2O + K_2O + CaO$	>1.1	<1.1
Transition metals	low	high
Temperature	lower	higher

Typical mineral assemblages

S-types: quartz + K-feldspar + plagioclase + biotite ± muscovite ± cordierite ± garnet ± andalusite ± ilmenite

I-types: quartz + plagioclase + K-feldspar + biotite ± hornblende ± sphene ± magnetite ± allanite

Restite model

- Linear variations in Harker diagrams in granite suites → inefficient separation of melt and solid residue (restite)
- melt and restite rise slowly in crust → slow separation (viscous magma)
- varying degrees of unmixing → develop a range of compositions → vary linearly on Harker diagram