The CA-IDTIMS Method and the Calibration of Endemic Australian Palynostratigraphy to the Geological Timescale*

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Abstract

The Permian portion of the International Geological Timescale has marine fossil zonations as its prime correlative tools. These comprise conodont, ammonoid, fusulinid and benthic foraminifera zonations, all defined in the northern hemisphere. During the Permian, eastern Australian was in high southern latitudes and largely nonmarine, making spore-pollen zonation the most effective local biostratigraphic scheme. Correlating this zonation to the global geological timescale has proven difficult at best. The reasons for this are twofold. Firstly, conodonts and fusulinids have never been found in the eastern Australian successions, and ammonoids are very rare. Secondly, the high latitude flora of the Permian (the Glossopteris flora) was largely endemic to the circumpolar Gondwanan continents, so precise correlation to the northern hemisphere is almost impossible. Despite this, a tentative calibration of the spore-pollen scheme against the timescale has been in use for some time, and is largely based on rare marine fossil occurrences.

The recently developed Chemical Abrasion-Isotope Dilution Thermal Ionisation Mass Spectrometry (CA-IDTIMS) technique, coupled with the plethora of tuffs in the nonmarine eastern Australian Permian, has provided an opportunity to calibrate the spore-pollen scheme directly to the International Geological Timescale. This has shown that the previous, tentative calibration is in need of considerable revision. For instance, the base of the Dulhuntyispora parvithola Zone was calibrated at about 263.5 Ma, in the early half of the Capitanian Stage. Our data clearly show that it lies within the lower half of the Wuchiapingian, at about 257.8 Ma. The base of the underlying Dulhuntyispora dulhuntyi Zone was calibrated at the base of the Capitanian (265.2 Ma). Our data demonstrate that it is, instead, Early Wuchiapingian, at about 258.2 Ma.

Preliminary data in the Triassic and Cretaceous indicate that similar dramatic changes in calibration may be required, with the base of the Triassic APT 4 being as much as 16 million years younger than currently assigned (Middle Norian rather than Late Ladinian), while the Cretaceous Cassiculosphaeridia delicata dinocyst zone may be as much as 3 million years younger, being early Valanginian rather than Middle Berriasian. These adjustments to the ages and durations of Australian biozones can have profound impacts on the evaluation of depositional rates and burial history models used in petroleum exploration.

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The CA-IDTIMS method and the calibration of endemic Australian palynostratigraphy to the Geological Timescale

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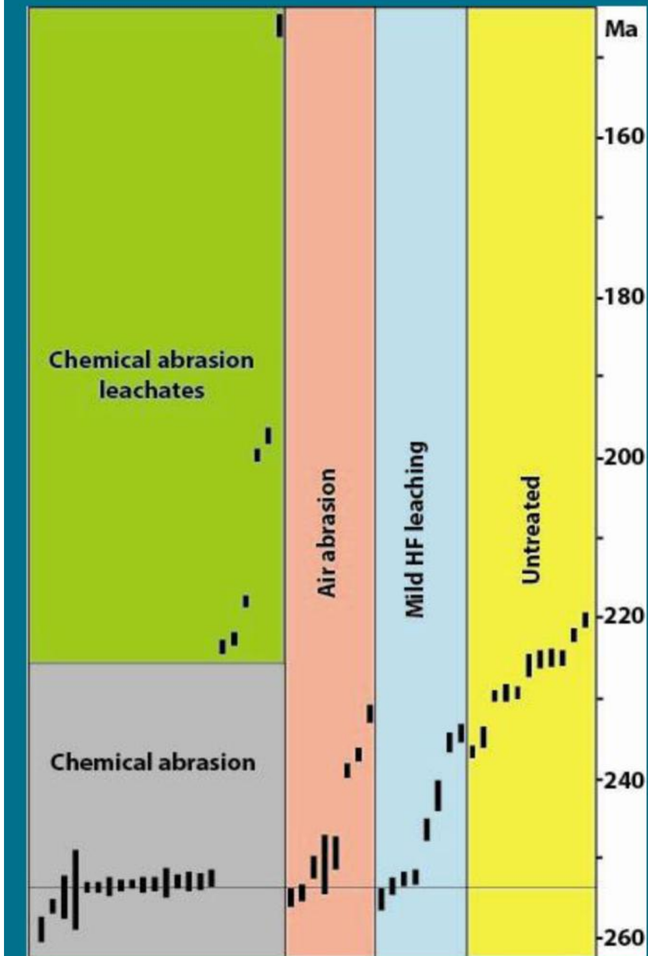
APPLYING GEOSCIENCE TO AUSTRALIA'S MOST IMPORTANT CHALLENGES

Presenter's notes: For some years now, Geoscience Australia has been involved in radioisotopic dating using a relatively new technique called Chemical Abrasion-Isotope Dilution Thermal Ionisation Mass Spectrometry (CA-IDTIMS), which is the abbreviation given here



Chemical Abrasion-Isotope Dilution Thermal Ionisation Mass Spectrometry (CA-IDTIMS)

Major problem with zircons is radiogenic lead loss from damaged parts of crystals

Analysing zircons which have suffered radiogenic lead loss gives misleading 'young' dates

Several methods were used to try to overcome this, none entirely successful

Mattinson (2000, 2005) developed the 'chemical abrasion' technique of annealing, followed by high-temperature, high pressure leaching in HF

Presenter's notes: One of the major difficulties with analysing zircons to obtain an estimate of the date of crystallisation is the problem of the loss of radiogenic lead from the crystal lattice.

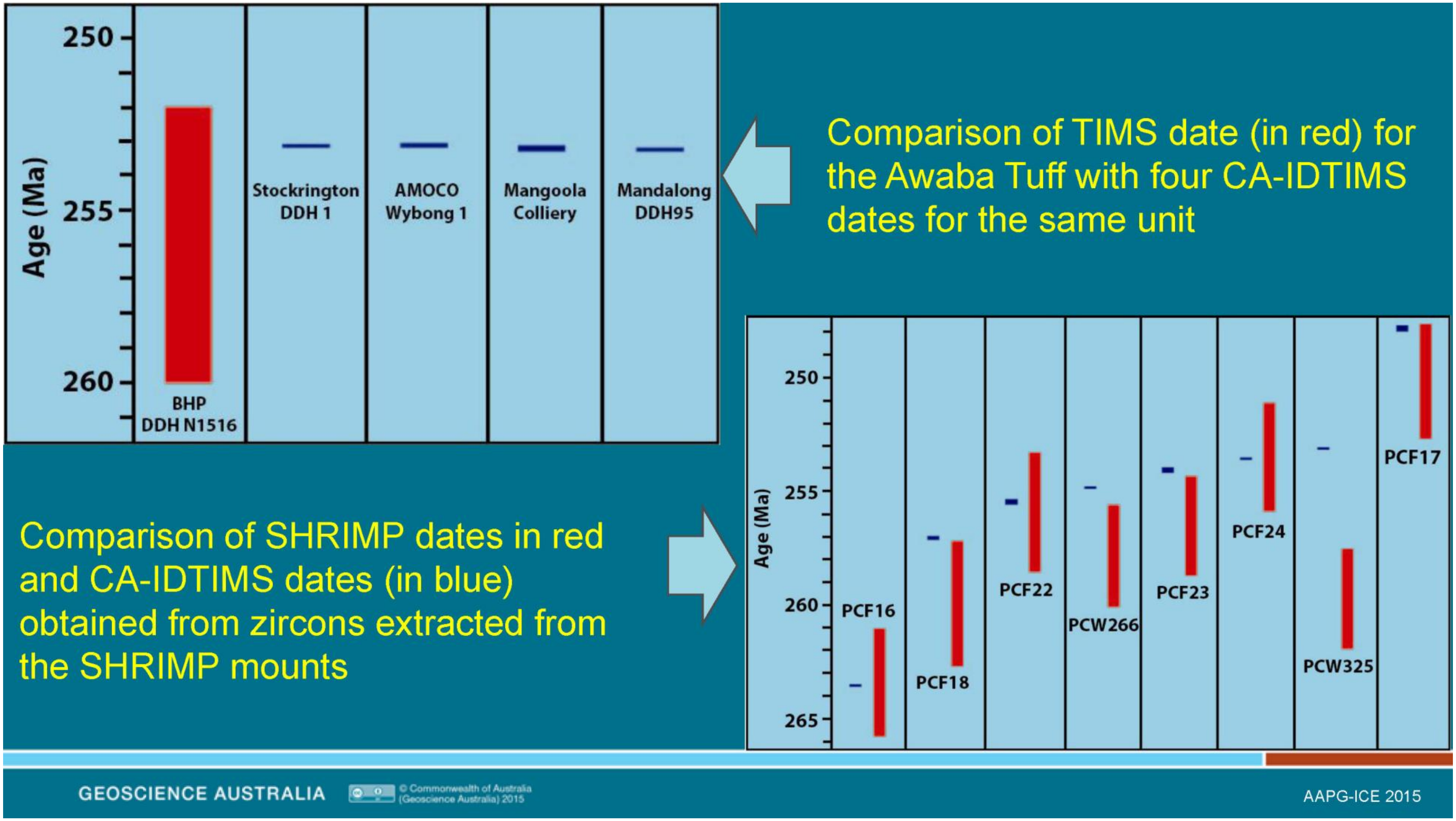
Analysing crystals which have suffered this problem tended to give 'bogus' dates which were significantly younger than the crystallisation date
This figure here shows analyses of zircons from a single horizon at about the Permian-Triassic boundary in the Chinese succession
Here you can see the results of analyses of untreated specimens (in the yellow), those which underwent mild HF leaching (in blue), and those which underwent air abrasion (in pink) to try to decrease the impact of lead loss. *(Presenter's notes continued on next slide)*

(Presenter's notes continued from previous slide)

As you can see, those which were untreated gave a smear of ages from about 240-220 Ma, much younger than the best estimate of roughly 252 Ma for the age of the sample.

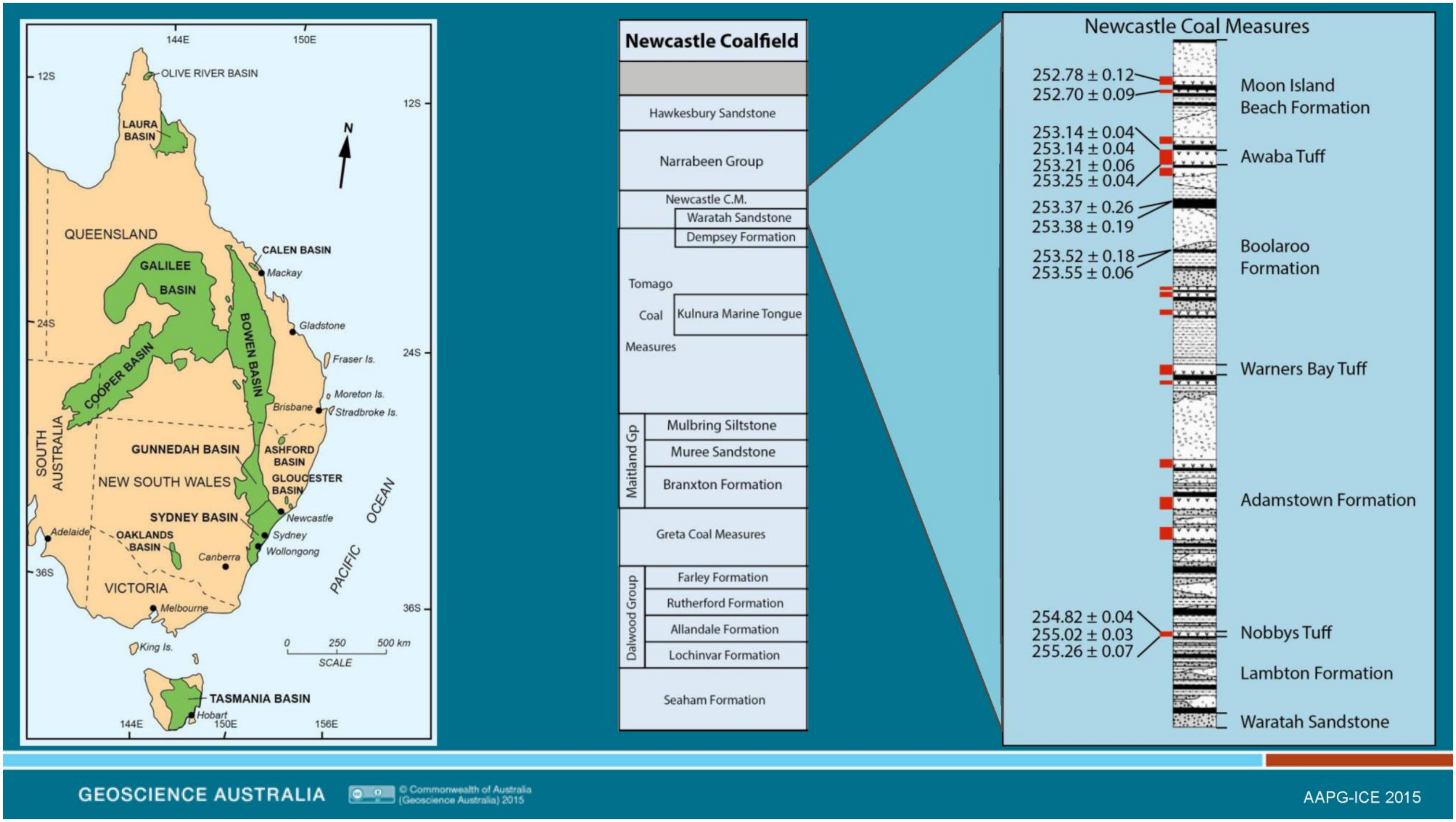
Those which underwent mild HF leaching still gave a smear of younger dates, but there were a few dates where they were expected to be
Those which underwent air abrasion showed a similar trend, while those that underwent the Chemical Abrasion technique (in grey) had a couple of older dates, with the remainder being where they were expected to be.

In the green are the leachates from the Chemical Abrasion technique. These demonstrate that the technique removes the parts of the crystals which have suffered the most severe lead loss.



Presenter's notes: Here we compare a couple of the other techniques used to date zircons with those using CA-IDTIMS.
In the upper panel, in red, we have a standard TIMS date from 1990, on zircons from the Awaba Tuff, a unit in the upper part of the Newcastle Coal Measures in the northern Sydney Basin. The vertical length of the bar indicates the 2-sigma confidence interval. Alongside, in blue, are four CA-IDTIMS dates from various sources but within the same unit. The length of these bars represents the 95% confidence interval. As you can see, the CA-IDTIMS dates are vastly more precise.

In the lower panel we have a series of SHRIMP dates in red, compared with CA-IDTIMS dates from zircons taken from the original SHRIMP mounts. These samples are in stratigraphic order with the lowest at the left and the highest at the right. As well as being much more precise, the CA-IDTIMS dates are consistent with stratigraphic position, whereas those from the SHRIMP analyses are not always so.



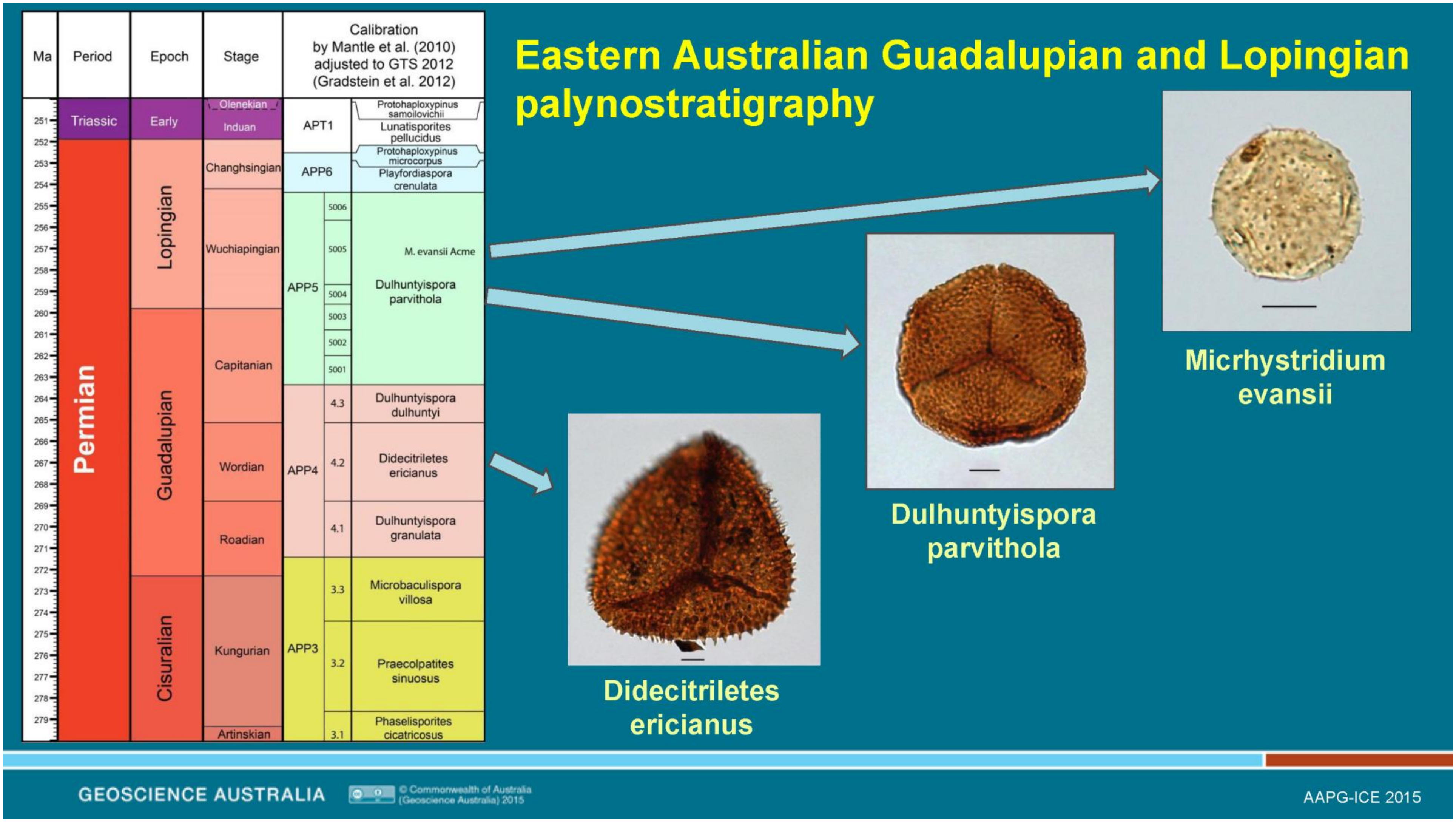
Presenter's notes: Volcanoes have been blowing their tops in eastern half of Australia from the Cambrian to the Holocene and this makes the region a prime candidate for isotopic dating of sedimentary successions. Initially our work has concentrated on the Permo-Triassic basins of eastern Australia as they are extensive and have been intensively studied because of their huge coal deposits.

The example stratigraphic column you see in the middle here, lists the main units of the succession in the Newcastle Coalfield of the northern Sydney Basin. These range in age from late Pennsylvanian at the base to middle Triassic at the top, with the Permo-Triassic boundary being at about the top of the Newcastle Coal Measures. *(Presenter's notes continued on next slide)*

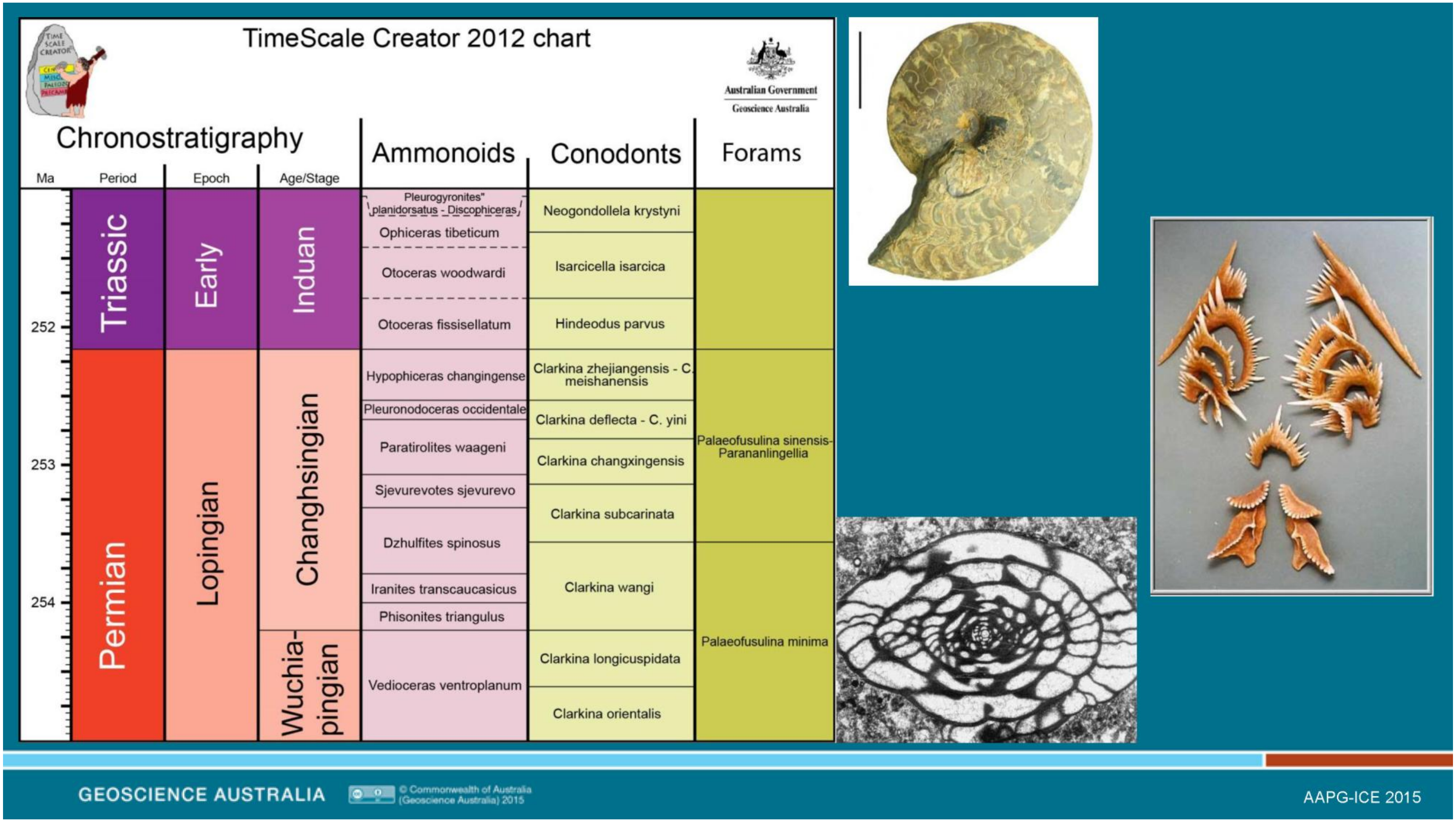
(Presenter's notes continued from previous slide)

This group-level unit shown on the right is about 450 metres thick and is divided into eight formations. Three of these are relatively thick tuffs, the Awaba, Warners Bay and Nobbys tuffs. While most of the thicker tuffs are shown here with red rectangles alongside, the remainder of the 140 or so are scattered throughout the succession and may be as thin as 1-2 centimetres. Indeed, tuffs are very common all throughout the Permian and Triassic succession of eastern Australia. This gives us an excellent opportunity to calibrate the lithostratigraphy and biostratigraphy of these basins.

The dates we have obtained from this unit, most of which are listed here, illustrate that the unit extends from about 256 Ma to 252 Ma, give or take a bit. This interval lies entirely within the error limits of the 1990 TIMS date obtained for the Awaba Tuff, and shown in the previous slide.

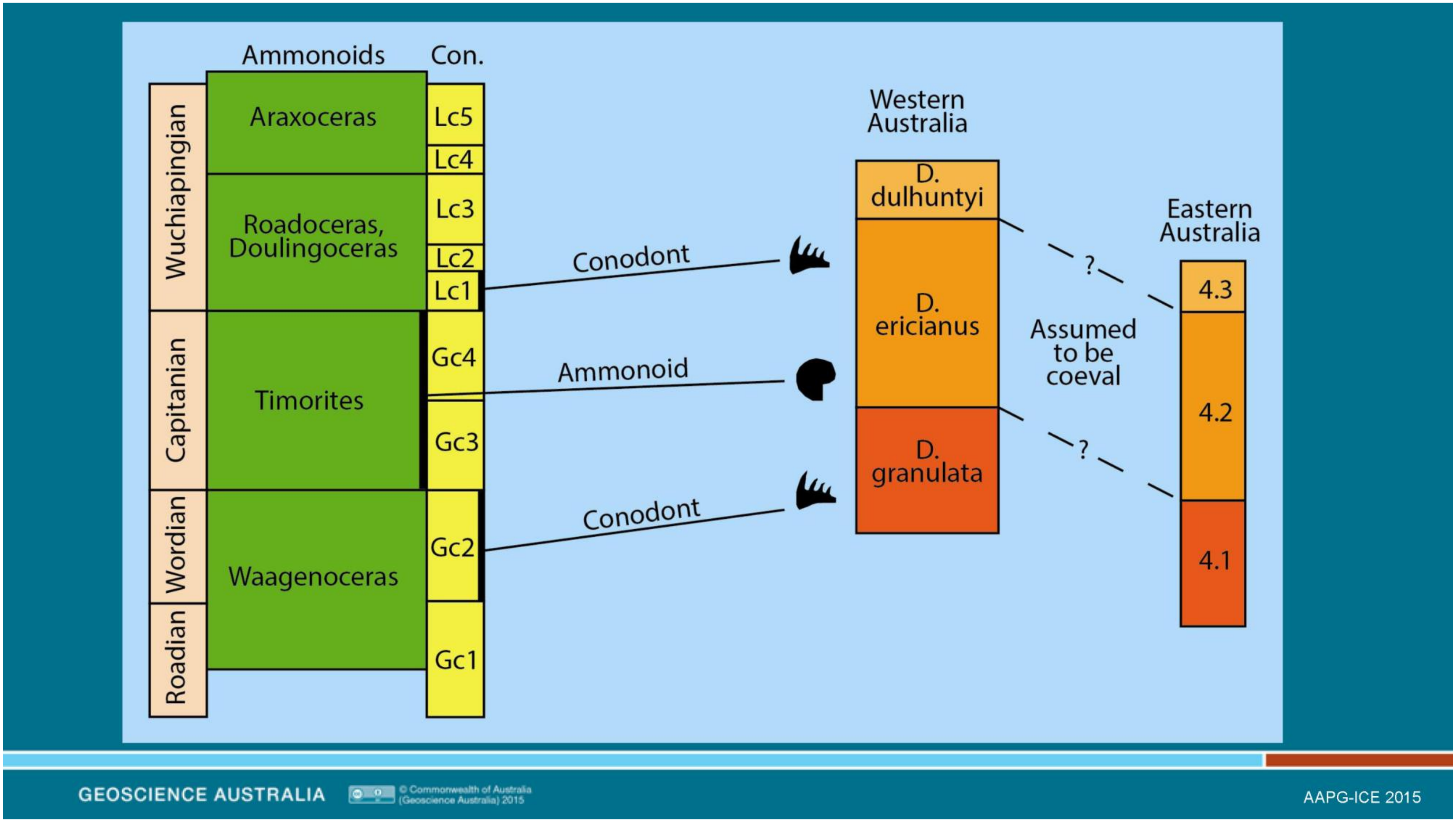


Presenter's notes: The Permian palynostratigraphic scheme developed by Price in 1997 is the standard used in eastern Australia. This is a column showing most of it as calibrated by Mantle and others in 2010 and updated to the 2012 timescale. Also shown are two cute little pollen grains and an acritarch.



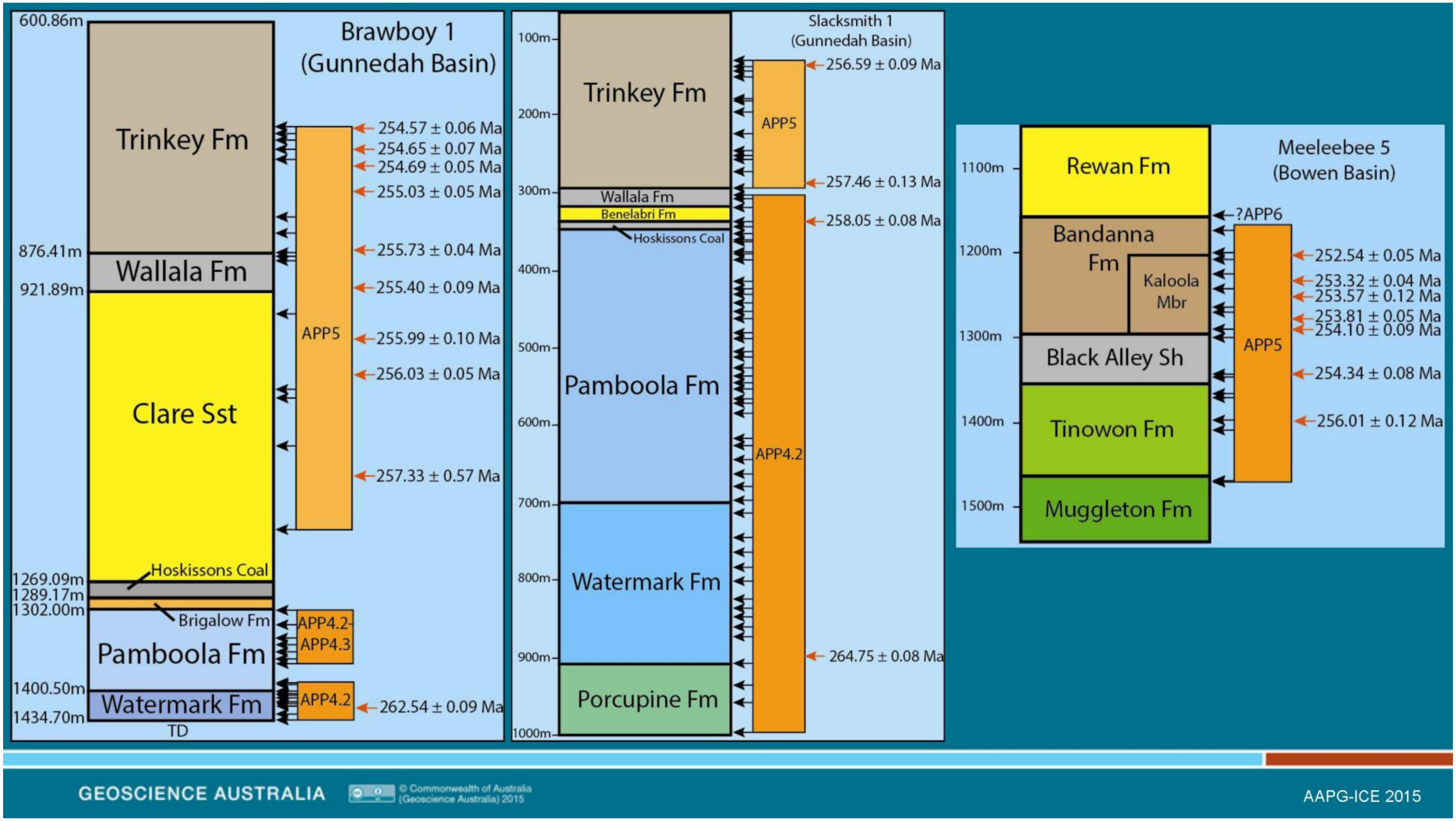
Presenter’s notes: Here is a short slab of the global standard Permian and early Triassic timescale extending from the Wuchiapingian in the late Permian to the Induan in the early Triassic. As you can see, the main taxa used for subdividing the column are Ammonoids, Conodonts and Fusulinid Foraminifera. The biostratigraphic schemes for the ammonoids and conodonts are fairly detailed, while that for the foraminifera is less so.

This scheme is mostly from the northern hemisphere, and in the eastern Australian Permian, no conodonts or fusulinid forams have ever been found, and ammonoids are very rare. This is presumably because, at that time, eastern Australia faced the cold southern Panthalassic Ocean. While fusulinids are also absent in Western Australia, ammonoids and conodonts have been found, but they are still not particularly common. Their presence is presumably because western Australia faced the warmer Mesotethys Ocean.



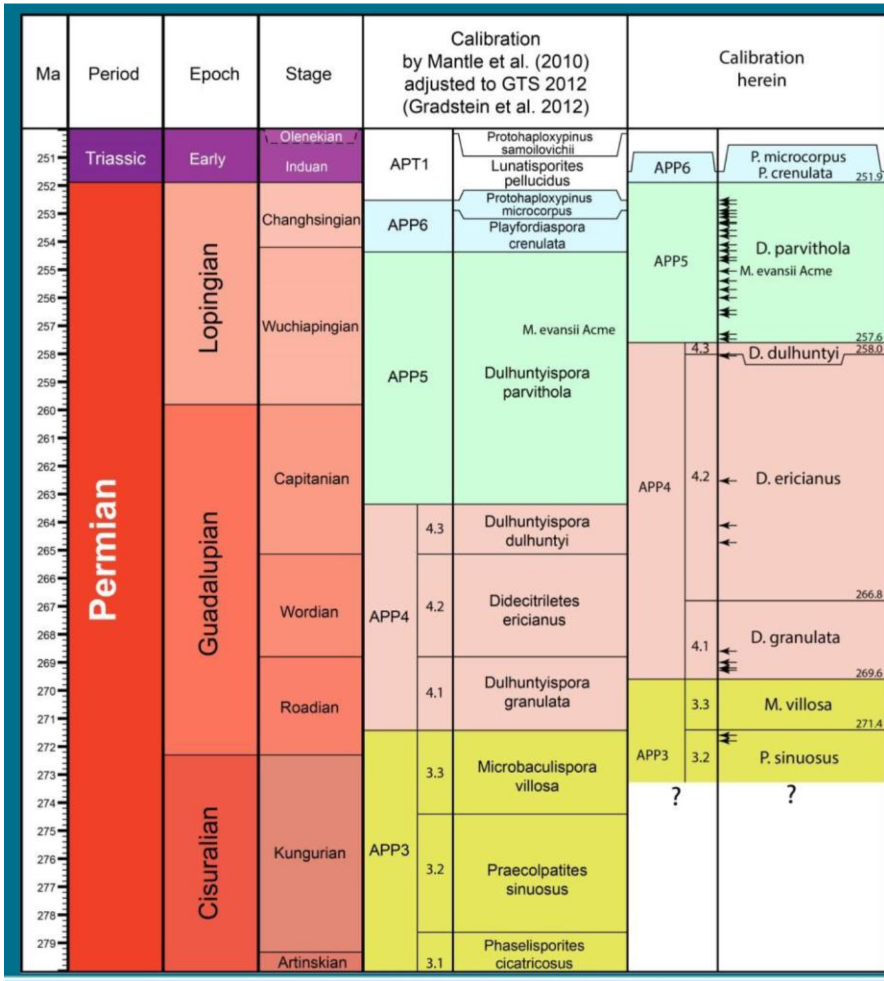
Presenter's notes: This a generalised diagram of how the numerical calibration of the endemic eastern Australian palynostratigraphic scheme is achieved. The eastern Australian zones are assumed to be coeval with those in Western Australia, then rare conodont and ammonoid occurrences are correlated with the standard northern hemisphere biostratigraphic schemes. Often the conodonts and ammonoids cannot be assigned to species, but only to genera, making the correlations even less precise.

As I am sure you can imagine, assigning numerical ages to the boundaries between these paly zones, based on such limited data, is fraught with difficulty and, in most cases, the numerical ages are simply half-way between scarce data points.



Presenter's notes: While it is useful to date lithostratigraphic units because such information can provide detailed understanding of depositional rates, diachroneity of units or baoundaries and the magnitude of hiatuses, we have concentrated on recalibrating the Australian palynostratigraphic scheme because it can be applied across any basin provided that basin contains rocks of a suitable age.

Here are details of three sampled wells from the Gunnedah and Bowen basins. At the left of each is the depth in the well. The main column indicates the lithostratigraphic units. The black arrows are samples biostratigraphically analysed by Geoff Wood of Santos for Brawboy 1 and Slacksmith 1 and by Tegan Smith and Dan Mantle for Meeleebee 5. The orange rectangles alongside them are the palynological zones to which they have been assigned. The red arrows represent our CA-IDTIMS dates. As you can guess from these diagrams, this gives us an excellent opportunity to calibrate the biostratigraphy.

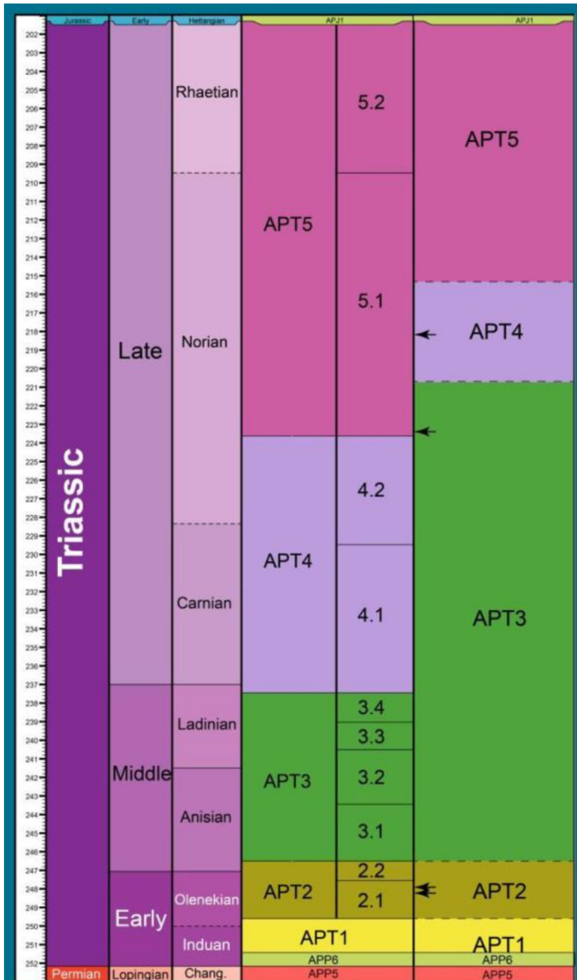


Recalibration of Guadalupian and Lopingian palynostratigraphy

Comparison of calibration of Mantle et al. 2010 (middle) with the revised version based on CA-IDTIMS dating (right)

Presenter's notes: This diagram shows our recalibration of the palynostratigraphy. To the left we have the standard Permian timescale, with the Mantle et al. (2010) calibration in the middle and the revised calibration at the right. Individual palynostratigraphically controlled CA-IDTIMS dates are represented by the little black arrows. As you can see, the data is sparse in some parts of the column, and there is still some refining to be done. The earlier part of the Permian is still under study.

It is abundantly clear that some of the changes in calibration are quite large. For example, the *D. parvithola* zone was thought to extend from the early half of the Capitanian to the late Wuchiapingian, whereas we now know that it extends from about the middle Wuchiapingian up to about the Permian-Triassic boundary. So, the base of the *D. parvithola* zone is about 6 million years younger than previously calibrated.

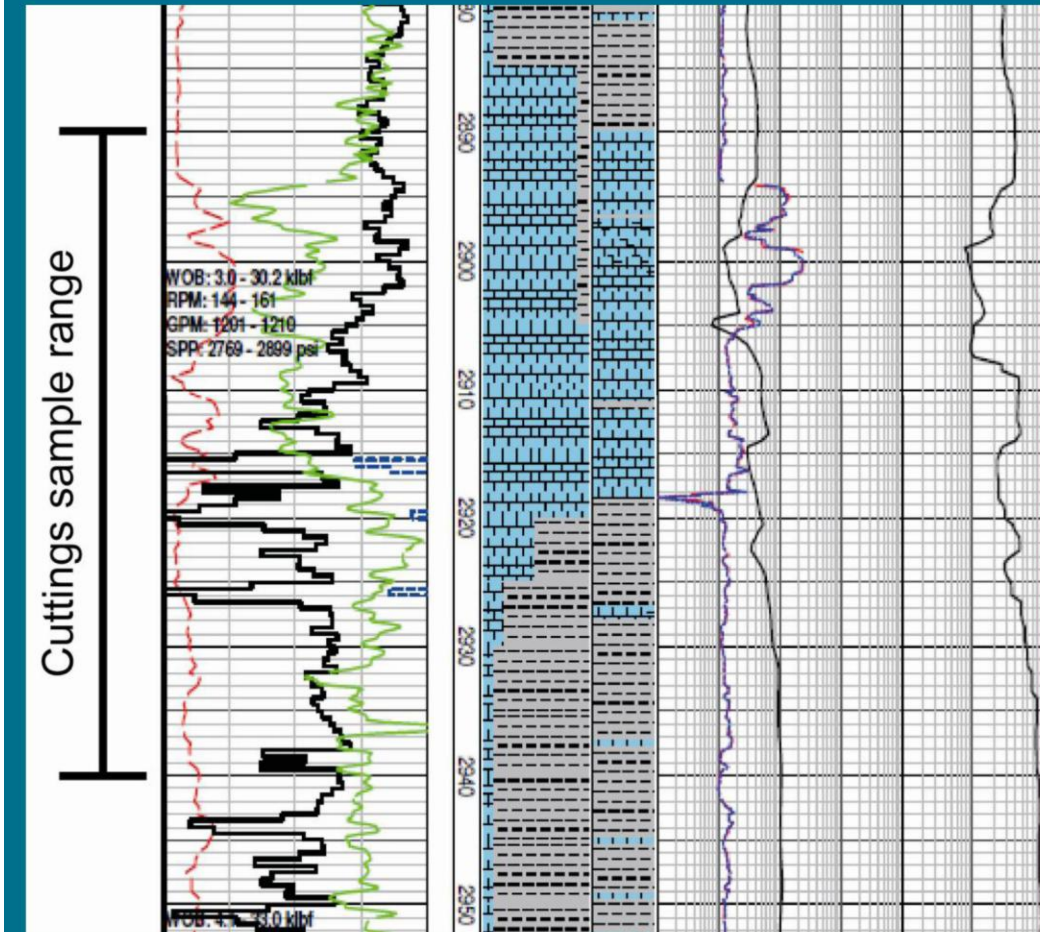


Preliminary recalibration of Triassic palynostratigraphy

Comparison of calibration of the Price (1997) APT zones by Mantle et al. 2010 (middle) with the revised version based on CA-IDTIMS dating (right)

Presenter’s notes: In addition to the Permian, we have some data from other time intervals.

Although we currently only have four dates in the Triassic, initial indications are that the Triassic palynostratigraphy is desperately in need of recalibration, just like the Permian. For instance, the top of the APT3 zone was considered to be late Ladinian by Mantle and others, whereas our information indicates that it is considerably younger, perhaps by as much as 17 million years. More data is needed if we wish to be as precise as we are in parts of the Permian.



Cretaceous cuttings on the NWS

SHRIMP: 139 ± 3 Ma

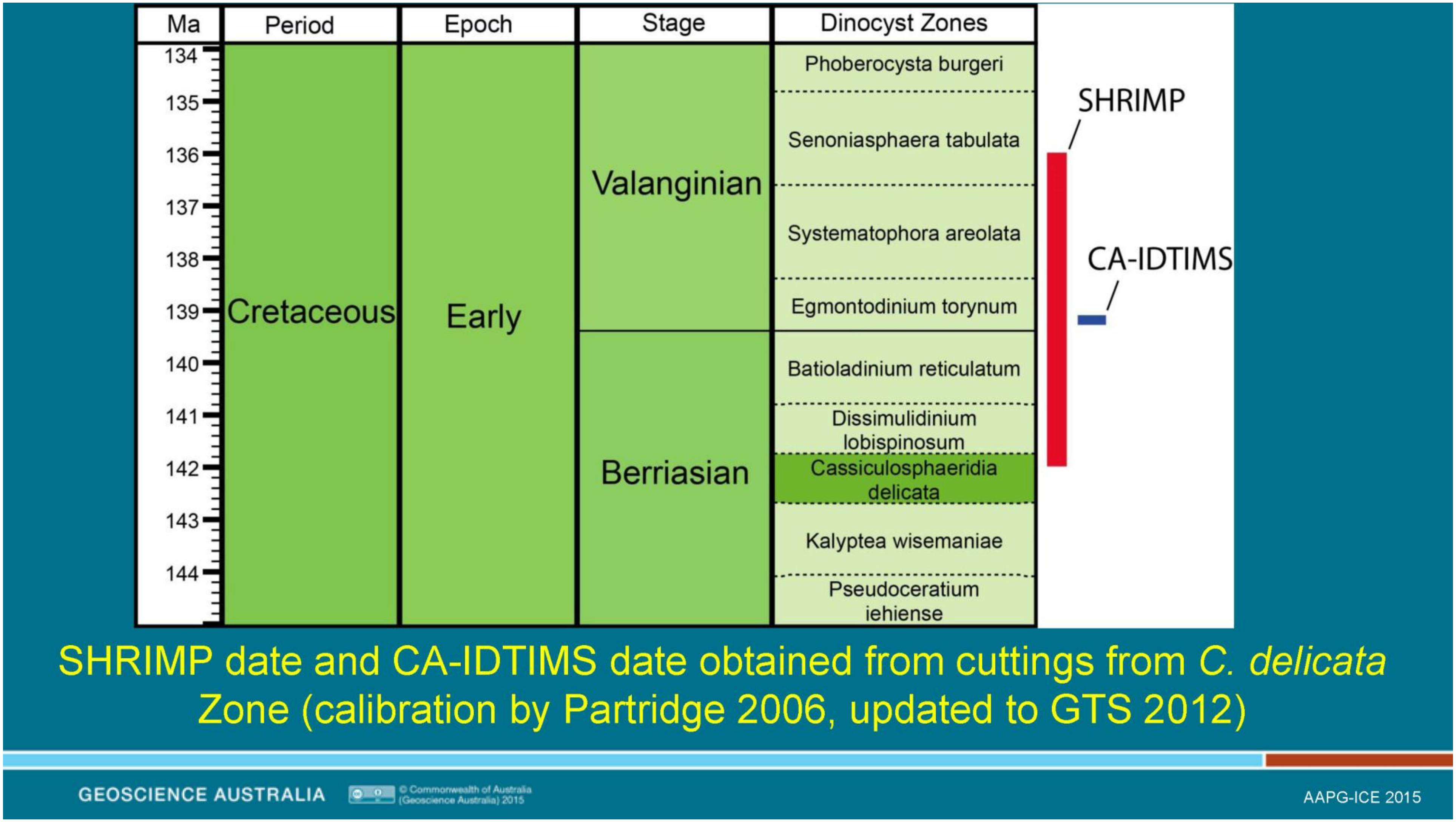
CA-IDTIMS: 139.15 ± 0.09 Ma

Dinocyst zone:
Cassiculosphaeridia delicata

Presenter's notes: When we first started to get indications that the Permian spore-pollen succession was miscalibrated, I discussed this with Alan Partridge and in my naiveté, assumed that the correlation of the mostly marine dinocyst zones would be in better shape.

He very quickly disabused me of that misapprehension, and this has been borne out by cuttings samples obtained from a still confidential well on the Northwest Shelf. This sample produced some pristine zircons and a nice dinocyst age determination of the early Cretaceous *Cassiculosphaeridia delicata* Zone.

These samples came from cuttings over a 50 metre depth range, which is a much larger interval than we would normally deal with. However, it did turn up an interesting result.



Presenter's notes: The sample was SHRIMPED and subjected to CA-IDTIMS dating. As you can see, the SHRIMP date and that obtained from CA-IDTIMS agree, with the latter having much more precision.

Despite all the uncertainties associated with determining the relative positions of palynomorph and zircon samples obtained from cuttings, the dating of these zircon samples indicates that the *Cassiculosphaeridia delicata* Zone is not middle Berriasian as originally calibrated by Partridge in 2006, but is possibly earliest Valanginian. If such differences as are indicated from our Triassic and Cretaceous data are common further up and down the timescale, it could have a significant impact on the understanding of the timing of events in several offshore basins.

Conclusions

CA-IDTIMS has revolutionised the application of radioisotopic dating to the calibration of biostratigraphy and lithostratigraphy

Previous calibrations of Australian Permian and probably all Mesozoic palynostratigraphic schemes are in need of significant revision

CA-IDTIMS dating allows us to bypass difficult and tenuous correlations to northern hemisphere biostratigraphic schemes and go directly to the numerical timescale

The greatest utility is attained by calibrating established biostratigraphic schemes rather than lithostratigraphic units.

Unlike lithostratigraphic units, once calibrated, biostratigraphic schemes can be applied beyond a single basin or sub-basin.

Presenter's notes: CA-IDTIMS has revolutionised the application of radioisotopic dating to stratigraphy. Before its development, we were able to roughly bookend stratigraphic successions, but now we can begin to calibrate each of the sedimentary packages within these successions.

Our work clearly illustrates that the various endemic Australian palynostratigraphic zonal schemes are in dire need of recalibrating to the numerical timescale. *(Presenter's notes continued on next slide)*

(Presenter's notes continued from previous slide)

Our work also demonstrates that the standard methodology of correlating local biostratigraphic schemes with the global timescale has significant problems, most of which are due to sparse data and biogeographic constraints. The combination of the precision (and presumed accuracy) of the CA-IDTIMS method and the presence of a large number of ashfall tuffs in eastern Australian successions allows us to circumvent these older methods and directly access the numerical timescale.

While it is possible to calibrate lithostratigraphic units, it was felt that the most efficient way to use our radioisotopic dates was for the calibration of the palynostratigraphic scheme. This can then be applied to any basin which has rocks (and fossils) of the appropriate age.

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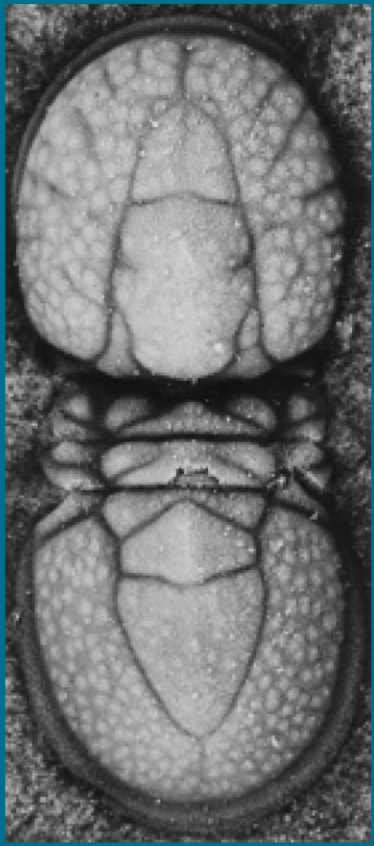
Santos,
University of Wollongong,
Xstrata



Presenter's notes: I acknowledge the institutions listed here for their support both financial and in-kind. Just for something different and larger than a speck of dust, this is a photograph of *Ptychagnostus punctuosus*, a lovely little middle Cambrian arthropod.

Thank You