Basin inversion and structural architecture as constraints on fluid flow and Pb-Zn mineralisation in the Paleo-Mesoproterozoic sedimentary sequences of northern Australia

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Abstract

As host to several world-class sediment-hosted Pb-Zn deposits and unknown quantities of conventional and unconventional gas, the variably inverted 1730-1640 Ma Calvert and 1640-1580 Ma Isa superbasins of northern Australia have been the subject of numerous seismic reflection studies with a view to better understanding basin architecture and fluid migration pathways. Strikingly similar structural architecture has been reported from much younger inverted sedimentary basins considered prospective for oil and gas elsewhere in the world. Such similarities suggest that the mineral and petroleum systems in Paleo-Mesoproterozoic northern Australia may have spatially and temporally overlapped consistent with the observation that basinal sequences hosting Pb-Zn mineralisation in northern Australia are bituminous or abnormally enriched in hydrocarbons. This points to the possibility of a common tectonic driver and shared fluid pathways. Sediment-hosted Pb-Zn mineralisation coeval with basin inversion first occurred during the 1650-1640 Ma Riversleigh Tectonic Event towards the close of the Calvert Superbasin with further pulses accompanying the 1620-1580 Ma Isa Orogeny which brought about closure of the Isa Superbasin. Mineralisation in all cases is hosted by the syn-inversion fraction of basin fill, contrary to most existing interpretations of Pb-Zn ore genesis where the ore-forming fluids are introduced during the rifting or syn-extensional phase of basin development. Syn-extensional normal faults of Calvert and Isa age are mutually orthogonal, giving rise to a complex compartmentalisation of sub-basins with predominantly NNW and ENE strikes. Basin inversion subsequent to 1640 Ma occurred in a transpressive tectonic regime linked to continent-continent collision accompanied by orogen-parallel extensional collapse and right-stepping strike-slip faulting.

Introduction

Northern Australia and its late Paleoproterozoic-early Mesoproterozoic basinal sequences have long attracted the interest of the minerals and petroleum exploration industries. Besides being the world's single largest repository of sediment-hosted Pb-Zn mineral deposits (Huston et al., 2006; Southgate et al., 2006), these same mineral-rich sequences hold some of the planet's oldest oil (Jackson et al., 1986) along with an unknown quantity of conventional and unconventional gas (Carr et al., 2019; Gorton and Troup, 2018; McConachie et al., 1993). Unsurprisingly, many mineral deposits and their host rocks are bituminous or contain very high proportions of carbon (Andrews, 1998; Broadbent et al., 1998; Hutton and Sweet, 1982; Jarrett et al., 2018; McConachie et al., 1993; McGoldrick et al., 2010), raising the possibility that the petroleum and mineralising systems in northern Australia may have temporally and spatially overlapped and share a common tectonic driver. Such a possibility was first entertained for the 1575 Ma Century Pb-Zn deposit (Fig. 1a) where first hydrocarbons and then a more metalliferous ore-forming fluid are thought to have been sequentially trapped following their expulsion from deeper stratigraphic levels during folding and thrusting accompanying the 1620-1575 Ma Isan Orogeny (Broadbent et al., 1998). In this scenario,

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this may be an issue of wording, but the similar structural architecture suggests basin inversion and nothing more. The fact that some inverted basins are prospective for oil and gas does not constrain the timing of migration or trapping. A more detailed discussion is required for this inference.

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the high TOC shales units are indicative of depositional environment only; the bituminous material indicates hydrocarbon migration but timing is not constrained

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you may not wish to be specific about which deposits in the abstract, but it needs to be clear in the figures and text

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show on time-space chart

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what is the setting for basin inversion at 1650-1640 Ma?

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this does not really come into the discussion so its more detail than required for the abstract

43 basin inversion was not only intimately linked to fluid migration and mineralisation but played a key role
44 in generating the structural architecture that brought the petroleum and mineralising systems together in
45 one place. Seismic reflection images for the Lawn Hill Platform have since shown the Century deposit to
46 be hosted by the syn-inversion fraction of basin fill (Gibson et al., 2017; Gibson et al., 2016) and occur in
47 rocks possessing a structural architecture common to inverted basins the world over, including those
48 currently under exploration for oil and gas in the Irish and North seas and north European continental shelf
49 more generally (Cooper et al., 1984; Hayward and Graham, 1989; Lowell, 1995; Thomas and Coward,
50 1995; Turner and Williams, 2004). Thus, not only does basin inversion appear to have been a prerequisite
51 for ore formation at Century but the structural architecture cannot have appreciably changed during the
52 transition from a hydrocarbon to mineral system lest the similarities with their more modern European
53 counterparts have been lost during crustal shortening. Such conclusions are difficult to reconcile with most
54 existing models for sediment-hosted Pb-Zn mineralisation in northern Australia where ore formation is
55 interpreted to have been syn-extensional and facilitated by fluid migration along normal faults active at the
56 time of basin formation (Huston et al., 2006; Kunzmann et al., 2019; Large et al., 2005; Leach et al., 2010;
57 McGoldrick et al., 2010). Alternative exploration strategies for this and other types of sediment-hosted Pb-
58 Zn mineralisation in northern Australia may therefore be warranted that better reflect the similarities with
59 the petroleum system and target the structures formed during basin inversion. Here, we make use of
60 publically available industry and government deep seismic reflection data to show that inversion-related
61 structures of more than one generation and style are widely developed in the late Paleoproterozoic-early
62 Mesoproterozoic basin sequences of northern Australia (Figs. 1 & 2), reflecting successive episodes of
63 crustal shortening during the course of which the majority of Pb-Zn deposits were emplaced (Gibson et al.,
64 2017).

65 **Regional geology and basin-forming events of northern Australia**

66 Northern Australia's late Paleoproterozoic-early Mesoproterozoic basinal sequences belong to one of three
67 superbasins (Figs. 2 & 3) which, together with the overlying and younger South Nicholson Basin (Fig. 1a),
68 preserve a 300 Myr history of lithospheric extension interrupted by successive episodes of basin inversion,
69 uplift and erosion (Betts et al., 2006; Blake, 1987; Gibson et al., 2012; Giles et al., 2002; Jackson et al.,
70 2000; O'Dea et al., 1997b; Southgate et al., 2000a; Withnall and Hutton, 2013). The oldest basin inversion
71 event (Fig. 3) occurred subsequent to 1840 Ma and is best expressed by the angular unconformity separating
72 the 6-8 km thick 1790-1740 Ma Leichhardt Superbasin (Fig. 2) from an older underlying $\geq$ 1870 Ma
73 crystalline basement (Kalkadoon-Leichhardt Block; Fig. 2) variably intruded by foliated 1860-1840 Ma
74 granites (Blake, 1987; Withnall and Hutton, 2013). Clasts of strongly foliated granite and other basement
75 rocks occur widely in conglomerates at the base of the Leichhardt Superbasin (1790 Ma Bottletree
76 Formation) but otherwise its basin fill is only mildly deformed and metamorphosed, and mainly comprises
77 continental tholeiites and rhyolite interstratified with subordinate but still substantial volumes of fluviatile-
78 shallow marine sedimentary rocks. This same cover-basement relationship is also evident on the Murphy
79 Ridge farther north where conglomerates (Westmoreland Conglomerate) at the base of the 1790-1740 Ma
80 Tawallah Group (Fig. 3) in the McArthur Basin (Fig. 1b) similarly rest unconformably on an older deformed
81 basement intruded by 1860-1840 Ma granites (Withnall and Hutton, 2013). As with the Kalkadoon-
82 Leichhardt Block, basement granites on the Murphy Ridge were deformed long before the overlying
83 conglomerate was deposited and likely represent exposed fragments of a much more regionally extensive
84 magmatic belt that is continuous at depth and once lay at or close to the eastern margin of the North
85 Australian Craton. Granites with calc-alkaline compositions occur widely throughout the Kalkadoon-
86 Leichhardt Block (Bierlein et al., 2011) and may originally have formed part of a continental magmatic arc
87 linked to west-dipping subduction beneath the eastern margin of the craton (Bierlein et al., 2008; Korsch et
88 al., 2012). Alternatively, these granites originated in a backarc setting linked to oceanward retreat of a more

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in many examples, the Pb-Zn orebody overprinted the high TOC unit that relates to depositional environment; the spatial overlap in these cases is localised at the hydrocarbon source

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is there any documented evidence on the timing of hydrocarbon migration at Century or other deposits?

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This paper discusses both syngenetic and diagentic models, but does not advocate one over the other. It also cites modelling by Sheldon and Schaubs 2017 (see reference list in Kunzmann for details) - that demonstrated that extension during Barney Ck deposition did not promote upward fluid flow, hence favouring a diagentic model with later fluid pumping possibly during a short lived compressional event.

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its a bit of an aside but this is unclear - continuous with what other units or in what direction? i.e with Kalkadoon or Tennant Ck or other granites?

89 distal arc built along either the southern or eastern margin of conjoined North and South Australian cratons
90 (Betts et al., 2016; Betts et al., 2008; Giles et al., 2002) or eastern margins (Gibson and Champion, 2019;
91 Gibson et al., 2018; Gibson et al., 2008). Regardless of which interpretation is correct, by 1790 Ma
92 lithospheric extension and thinning were well underway and northern Australia was subjected to
93 widespread intracontinental rifting, normal faulting and half-graben formation accompanied at deeper
94 crustal levels to elevated heat flow, low pressure-high temperature metamorphism and bimodal magmatic
95 intrusion (Betts et al., 2016; Betts et al., 2006; Gibson et al., 2012; Gibson et al., 2008; Giles et al., 2002;
96 Giles et al., 2004; Holcombe et al., 1991; O'Dea et al., 1997a; Pearson et al., 1991). Lithospheric extension
97 during this phase of basin formation produced mainly northwest-oriented normal faults and half-graben and
98 continued through until ca. 1740 Ma when backarc extension and rifting in the Mount Isa region and
99 neighbouring McArthur Basin (Fig. 1a) temporarily ceased and gave way to an episode of thermal
100 subsidence accompanied by the deposition of shallow marine quartzite and carbonate rocks (Gibson et al.,
101 2012; Jackson et al., 2000; O'Dea et al., 1997b) .

102 The Leichhardt Superbasin concluded in a period of renewed tectonic instability variously attributed to
103 onset of a 1730-1710 Ma orogenic event (Blaikie et al., 2017) or a renewal in fault-block rotation and tilting
104 (Gibson et al., 2012; Gibson et al., 2008). Either way, uplift and erosion accompanying this event resulted
105 in the formation of a deeply incised and regionally extensive angular unconformity above which
106 conglomerates and redbeds of the Bigie Formation were deposited (Fig. 3). Their deposition marks the start
107 of the 1730-1640 Ma Calvert Superbasin (Figs. 2 & 3) and corresponds to a resumption in backarc
108 extension, bimodal magmatism and rift-related sedimentation (Gibson et al., 2016; Jackson et al., 2000;
109 Southgate et al., 2000a). Both NW-SE and NE-SW extensional directions have been proposed for the
110 Calvert Superbasin (Fig. 3) and questions remain about the primary orientation of half-graben hosting the
111 bulk of basin fill. In the McArthur Basin, this includes basaltic rocks of the 1730-1720 Ma Peters Creek
112 Volcanics and Top Rocky Rhyolite (Rawlings et al., 2008) whereas farther afield on the Lawn Hill Platform
113 (Fig. 1a), the Calvert Superbasin hosts basalts of the 1710-1705 Ma Fiery Creek Volcanics (Fig. 3) and
114 fluviatile-shallow marine sediments of the 1700-1690 Ma Surprise Creek Formation (Fiery and Prize
115 Supersequences; Southgate et al., 2000). At about the same time that these rocks were being laid down
116 across the Lawn Hill Platform, water depths began to substantially increase farther east in the Mount Isa
117 region so that by 1690 Ma basaltic magmas were being extruded and/or intruded into a deep marine basin
118 filled with turbidites (Black et al., 1998; Foster and Austin, 2008; Gibson et al., 2018; Gibson et al., 2012;
119 Giles et al., 2002; Glikson et al., 1976; Neumann et al., 2009; Rubenach et al., 2008; Scott et al., 2000;
120 Withnall, 1985). Basaltic magmatism continued through to 1655 Ma in the east by which time the
121 Leichhardt Superbasin and lower parts of the Calvert Superbasin had also been intruded farther west by
122 1680-1670 Ma A-type granites (Sybella Granite)(Neumann et al., 2006) and partially unroofed on top-to-
123 the-northeast extensional shear zones (Gibson et al., 2008).

124 With the conclusion of bimodal magmatism 2 : 1655 Ma, the tectonic setting of the Calvert Superbasin
125 transitioned from 3 ackarc basin to passive rifted continental margin (Baker et al., 2010; Gibson et al., 2018;
126 Gibson et al., 2012; Neumann et al., 2009) and began to cool and subside, precipitating a marine
127 transgression during the course of which the North Australian Craton was buried beneath a post-rift
128 sequence (Gun Supersequence; Fig. 3) of thin-bedded turbidites, carbonaceous shales, black dolomitic
129 siltstones and carbonate rocks that extended westwards as far as the McArthur Basin (McArthur Group;
130 Fig. 3) and Lawn Hill Platform (Betts et al., 2016; Betts et al., 2006; Gibson et al., 2012; Gibson et al.,
131 2017; Southgate et al., 2013; Withnall and Hutton, 2013).

132 Passive margin conditions persisted until circa 1650 Ma by which time northern Australia was subjected to
133 a further episode of basin inversion (Fig. 3) 4 at lasted until at least 1640 Ma (Riversleigh Tectonic Event)
134 and brought sedimentation in the Calvert Superbasin to a close (Gibson et al., 2018; Gibson et al., 2017;

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Big and Prize

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Fig 3 shows sag starting just after 1670

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If River SS is syn-extensional (e.g. Bradshaw and Scott, 1999) and includes units as old as ca 1647 Ma then inversion should end before 1640. Or do you interpret River SS as syn-inversion?

135   Hinman, 1995; Withnall and Hutton, 2013). Thereafter, the tectonic environment fundamentally changed
136   and crustal extension resumed in a north-south direction (Fig. 3), giving rise to the 1640-1580 Ma Isa
137   Superbasin (Fig. 2) and deposition of a further 6-8 km of sandstone, carbonaceous shales, and dolomitic
138   siltstones (Riversleigh and Term supersequences) in fault-bounded basins predominantly oriented ENE-
139   WSW (Bradshaw et al., 2000; Bradshaw et al., 2018; Gibson et al., 2020; Gorton and Troup, 2018). Despite
140   the resumption in crustal extension, basaltic rocks are absent and, save for a few tuff beds, there was no
141   corresponding resurgence in felsic magmatism until after the Isa Orogeny had concluded at ca. 1590-1580
142   Ma, some 50-60 Ma later (Black and McCulloch, 1990; Gibson et al., 2018; Withnall and Hutton, 2013).
143   The absence of any significant magmatism is in stark contrast to the two older superbasins, leading some
144   researchers to conclude that the Isa Superbasin represents a sag basin, albeit one periodically punctuated
145   by crustal extension (Betts et al., 2003; Betts et al., 2006), whereas others have argued for deposition in a
146   foreland setting (McConachie and Dunster, 1996), pull-apart basin (Scott et al., 1998; Scott et al., 2000;
147   Southgate et al., 2000a) or syn-orogenic basin in which extension was facilitated by orogen-parallel strike-
148   slip faulting and lateral extrusion of continental crust (Gibson et al., 2020; Gibson et al., 2017). This episode
149   of orogenesis concluded at ca. 1590 Ma (Gibson et al., 2020) or possibly as late as 1580 Ma (Pourteau et
150   al., 2018) before being followed by further crustal extension and successive episodes of pluton-enhanced
151   low pressure-high temperature metamorphism at 1560-1540 Ma and 1520-1490 Ma (Duncan et al., 2011;
152   Foster and Rubenach, 2006; Rubenach et al., 2008). Granitic rocks associated with this late metamorphism
153   have both A- and S-type compositions and are mainly to be found in the east where they are demonstrably
154   of post-tectonic origin, truncating and cutting across folds and axial plane fabrics produced during the Isan
155   Orogeny (Foster and Austin, 2008; Giles et al., 2006; Page and Sun, 1998; Pollard and McNaughton, 1997;
156   Pollard et al., 1998; Withnall and Hutton, 2013).

157   With the conclusion of granitic magmatism at 1500 Ma, much of northern Australia was uplifted and eroded
158   before being buried again beneath younger rocks of the 1490-1450 Ma South Nicholson Basin (Sweet,
159   2017). This Mesoproterozoic basin directly overlies the Isa Superbasin in areas to the west and north of the
160   Lawn Hill Platform (Fig. 1a) and has recently been the subject of a deep seismic reflection study (Carr et
161   al., 2019). Although the seismic data were primarily acquired with a view to better understanding the
162   geometry, thickness and lateral dimensions of this younger basin (Fig. 4), they also serve as a window on
163   the deeper subsurface geology all the way down to crystalline basement and beyond (Carr et al., 2019),
164   thereby providing an opportunity to compare basin architecture in the older sequences below this basin with
165   the results of previous seismic reflection surveys and across a greatly expanded geographical area
166   (Bradshaw et al., 2018; Bradshaw and Scott, 1999; Gibson et al., 2016; McConachie et al., 1993; Scott et
167   al., 1998). These previous seismic reflection surveys highlighted the asymmetric nature of faulting and
168   basin development across the Lawn Hill Platform but differed in respect to basin history and evolution, and
169   more particularly the record of basin inversion and its tectonic drivers (Scott et al., 1998; Gibson et al.,
170   2016; see also Betts et al., 2004). By virtue of the increase in seismic coverage, these issues have become
171   more amenable to investigation and it is to these aspects of basin history and evolution in northern Australia
172   that we now turn.

Seismic record of basin formation and inversion in northern Australia

174   Survey lines for seismic reflection data acquired across the Lawn Hill Platform and already in the public
175   domain are shown in Figure 5. Most of these are legacy lines dating back to the late 1980s and early 1990s
176   (Burketown Survey, Comalco)(McConachie et al., 1993) and for which reprocessed data became available
177   in 2014 (Armour Energy). Other lines (Fig. 6a & 6b) were acquired by the minerals industry (Teck
178   Resources, 2011) or minerals industry in collaboration with state and federal Governments (Zinifex,
179   Geological Survey of Queensland and Geoscience Australia, 2006), interpretations of which can be found
180   in several publications and Government records (Bradshaw et al., 2018; Bradshaw and Scott, 1999; Gibson

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River SS

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lowercase

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Amour

181 et al., 2017; Gibson et al., 2016; Krassay et al., 2000b; Scott et al., 1998; Southgate et al., 2000b). Results
182 and interpretations of the more recent 2017 South Nicholson Basin survey (Fig. 4) were published jointly
183 by Geoscience Australia and the geological surveys of Queensland and the Northern Territory (Carr et al.,
184 2019) although their interpretation of geology beneath the Carrara Sub-basin (Fig. 4) 1 not exactly the same
185 as the one presented here, in part owing to uncertainties in extrapolating stratigraphy from existing seismic
186 lines into areas of little or no outcrop or exploratory drilling. A few rare outcrops of basement schist and
187 2 arrara Range Group rocks intruded by 1725 Ma Top Rocky Rhyolite (Jackson et al., 2000; Rawlings et
188 al., 2008) are known from the southern Carrara Range immediately north of seismic line 017GA-SN1 but
189 otherwise older parts of the regional stratigraphy are not well exposed, including basaltic rocks (Mitchiebo
190 Volcanics) 3 ong thought to be correlative of the Eastern Creek Volcanics in the Leichhardt Superbasin (Fig.
191 3). In a further departure from previously published interpretations of existing seismic data (Gibson et al.,
192 2017), the Calvert and Isa superbasins are both thought here to comprise discrete syn- and post-inversion
193 sedimentary fractions (Fig. 3). These broadly conform with the sedimentary units or supersequences
194 previously identified at the top of each superbasin (Bradshaw et al., 2000; Bradshaw et al., 2018; Domagala
195 et al., 2000; Krassay et al., 2000a; Krassay et al., 2000b; Southgate et al., 2000a) and have an important
196 bearing on basin evolution, and more particularly on the timing and duration of the basin inversion events
197 that brought successive basin cycles to a close. These and other differences with previously published
198 interpretations can be illustrated with a few well-chosen survey lines and there is no need to include
199 interpretations of the full seismic dataset. All lines chosen here are composite and make for two orthogonal
200 but not completely continuous transects across the Lawn Hill Platform, Carrara Range and neighbouring
201 Carrara Sub-basin (Fig. 5). For an alternative and slightly different interp 4 ation of these and other lines in
202 the dataset, the reader is referred to Bradshaw and Scott (5 009) 6 radshaw et al (2018) and Carr et al (2019).

North-south seismic transect across Lawn Hill Platform

204 This composite transect is made up of several segments (Figs. 6a & 6b) oriented at high angles to the
205 dominant ENE trend of the Isa Superbasin (Fig. 5). Collectively, these segments image a variably inverted
206 southward-thickening sedimentary wedge disrupted by faults and bounded at its top and bottom by major
207 unconformity surfaces. Limited outcrop across the Lawn Hill Platform and ties to cross lines for which oil
208 well stratigraphic data are available (Fig. 5 & 7) would further suggest that the greater part of this wedge
209 comprises rocks of the Calvert and Isa superbasins (Bradshaw et al., 2000; Bradshaw and Scott, 1999;
210 Gorton and Troup, 2018; Scott et al., 1998; Southgate et al., 2000a) and that the Leichhardt Superbasin is
211 either missing or reduced to a thin layer sandwiched between basement and the overlying younger basins
212 (Figs. 6a & 6b). All five supersequences of the Isa Superbasin (Fig. 3) are represented in the seismic
213 sections, with the base of the sequence 7 eaching extending to depths of 5-6 km along Comalco line 91Bn33-
214 91Bn28 (Fig. 6a). Basin architecture along this line was first described in detail by 8 radshaw et al (2000)
215 and their interpretation of inversion-related structures in the River and Term supersequences is not
216 dissimilar to the one presented here. More specifically, as in Bradshaw et al (2000), several inverted normal
217 faults are recognised along this line into which both the 9 iver and Term Supersequences manifestly thicken
218 (Fig. 6a); they typically dip northward and even though some of these same faults disrupt and offset
219 sedimentary units in the underlying Calvert Superbasin (Loretta and Prize supersequences, there is 10
220 evidence in the seismic section that these structures ever served as growth faults during deposition of the
221 older sedimentary basin. Rather, these north-dipping faults cuts across and postdate stratigraphy in the
222 Calvert Superbasin, and first became active during deposition of the younger Isa Superbasin. No less
223 importantly, both the River and Term supersequences continue southward across the Bluewater Fault Zone
224 into the hangingwall of the Tin Tank Fault where stratigraphy is even more spectacularly inverted (Fig. 6a)
225 and has been deformed into an asymmetric, km-scale south-verging antiform (Punjaub Structure). The

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is strikingly different

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Although the Top Rocky Rhyolite includes porphyry; it also includes units that are clearly extrusive; if you want to argue that the Carrara
Range Group is older than ca 1725 Ma, then the outcrop observations and age data need to be discussed.

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references? The Mitchiebo Volc are not dated, but the other units of the group are.
see more detailed comments in summary discussion

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punctuation

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1999

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wording

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minor point, but if you are specifically referring to the seismic interpretation then Bradshaw and Scott 1999 came first

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 supersequences - lower case

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I would disagree based on Figure 6; there are a lot of thickness changes in the Calvert SB

226 River and Term supersequences both attain maximum stratigraphic thickness between the Bluewater and
227 Tin Tank fault zones and occupy much of the fold core (Fig. 6a).

228 Conversely, owing to the effects of erosion, the overlying Lawn and Wide supersequences are only partially
229 preserved over the crest of the antiform. Even so, enough survives of both units beneath their Mesozoic
230 cover rocks to show that these two units progressively thinned over the crest of this fold through a
231 combination of onlap and truncation (Fig. 6a), indicating that the Punjaub Structure either already existed
232 by the time these two units were being deposited or was actively growing during their deposition. In either
233 event, and contrary to previous interpretations (Bradshaw et al., 2000), these two units cannot therefore
234 form part of the syn-extensional growth package. Rather, extension in the Isa Superbasin had already come
235 to a close before sedimentation ceased and these two units more rightly belong to the syn-inversion fraction
236 of basin fill. This is the same conclusion reached by Gibson et al (2017) for the Lawn and Wide sequences
237 exposed along seismic line 06GA-M2 in the Century region farther south (see below).

238 It is further evident from the abrupt truncation of older Calvert-age stratigraphy at the base of the River
239 Supersequence in seismic section 91Bn33-91Bn28 (Fig. 6a) that rocks of the Lawn Hill platform were
240 subjected to an earlier phase of basin inversion, uplift, and erosion before sedimentation in the Isa
241 Superbasin had even started (Bradshaw et al., 2000; Bradshaw et al., 2018; Gibson et al., 2020; Gibson et
242 al., 2017; Scott et al., 1998; Southgate et al., 2000b). As much as 1700m of sedimentary section is estimated
243 to have been lost from the Calvert Superbasin during this inversion event (Bradshaw et al., 2000), a
244 significant amount of which may have been redeposited farther south in the Leichhardt River Fault Trough
245 (Fig. 1a) where there was a commensurate influx of quartz sand at or just before 1640 Ma (Southgate et al.,
246 2000b) during the closing stages of the Calvert Superbasin (Gibson et al., 2017). Truncation of the Calvert
247 Superbasin beneath the River Supersequence is also evident in the Century area (Gibson et al., 2017) and
248 may be further inferred from onlap of the River Supersequence onto older folded rocks of the Calvert
249 Superbasin at depth beneath Mount Caroline (Fig. 6b). Folding of the same amplitude and intensity is not
250 replicated in the overlying River Supersequence and younger sedimentary units, and appears to be confined
251 to the Calvert-age rocks. As elsewhere in the region, the existence of these older structures has largely
252 gone unrecognised owing to extensive overprinting or tightening during the 1620-1580 Ma Isa Orogeny
253 and at least one younger shortening event that postdates the Isa Orogeny and folded all units up to and
254 including the South Nicholson Basin (Fig. 6a). At least some of the folding observed in younger
255 stratigraphic units around the Punjaub Structure may also date from this younger shortening event as is
256 some of the deformation associated with the two northeast-trending periclinal folds (Ploughed Mountain
257 and Mount Caroline) developed northeast of the Century Mine (Fig. 1b). Even more striking are the steep
258 (Boga Fault) and low angle reverse faults that disrupt the core of the Punjaub Structure and cut up section
259 all the way to the Wide Supersequence (Fig. 6a) and may themselves have been folded or reactivated during
260 a younger deformational event.

261 **West-east seismic transect through the Calvert and Isa superbasins**

262 As in the first transect (Fig. 6), seismic sections oriented west-east reveal a wedge-like basin geometry
263 except that units thicken westwards (Fig. 7a & 7b) rather than southward. This is particularly evident in the
264 Isa Superbasin whose constituent lithologies likely occupy a large half-graben that diminishes in depth both
265 laterally and at right angles to the normal faults bounding its southern margin (Fig. 5). As north-dipping
266 structures, these faults are effectively rendered "invisable" in the seismic data. Conversely, growth faults
267 of Calvert age in most seismic sections are well imaged and dip towards the east or northeast (Figs. 7a &
268 7b). They have effected varying amounts of differential thickening and in some instances cut up-section no
269 farther than the Loretta Supersequence at the top of the basin as would be expected of growth faults of this
270 age. A notable exception is the Riversleigh Fault into which stratigraphic units of both the Calvert and Isa

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T Number: 1   Author: uqkconn5   Subject: Highlight   Date: 1/05/2020 5:04:56 PM
this is indicated by symbols, but the reader cannot see the onlap relationship; an enlargement of this area would be beneficial to support the syn-inversion timing

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T Number: 2   Author: uqkconn5   Subject: Highlight   Date: 1/05/2020 5:05:32 PM

T Number: 3   Author: uqkconn5   Subject: Highlight   Date: 1/05/2020 5:06:38 PM
I thought Bradshaw and Scott 1999 included both Wide and Doom as syn-inversion; did the 2000 paper change this interpretation?

T Number: 4   Author: uqkconn5   Subject: Highlight   Date: 1/05/2020 5:09:51 PM
where did max erosion occur? from the top of the Murphy Inlier to the north of Fig 6a

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T Number: 5   Author: uqkconn5   Subject: Highlight   Date: 6/05/2020 11:10:48 AM
deposited as which units? It would be helpful to clarify given your younger boundary between Loretta and River on Fig 3

T Number: 6   Author: uqkconn5   Subject: Highlight   Date: 1/05/2020 5:13:01 PM
Fig 6a shows significant folding of River and younger sequences

> Author: uqkconn5   Subject: Sticky Note   Date: 3/05/2020 6:21:06 PM
> or are you just referring to 6b; i don't see a dramatically different amplitude in the older rocks

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T Number: 7   Author: uqkconn5   Subject: Highlight   Date: 1/05/2020 5:11:58 PM
please show location

T Number: 8   Author: uqkconn5   Subject: Highlight   Date: 1/05/2020 5:20:57 PM
it is relevant to note that 7a is NE-SW given your emphasis on the direction of thickening

> Author: uqkconn5   Subject: Sticky Note   Date: 1/05/2020 5:27:48 PM
> This line highlights thinning and onlap to the north; and thickening to southwest

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T Number: 9   Author: uqkconn5   Subject: Highlight   Date: 6/05/2020 11:15:14 AM
7b is E-W but is subparallel to the ~E-W Doomadgee fault which cuts in and out of the seismic section (Bradshaw et al. 2018; as well as Bradshaw and Scott, 1999); Bradshaw et al. (2018) show that there are NW trending faults in this area as well (consistent with regional interpretations). You note there are Isa SB fault parallel to the line that cannot be shown, but the detailed mapping by Bradshaw et al suggests the line cuts in and out of the line and should therefore be evident.

T Number: 10   Author: uqkconn5   Subject: Highlight   Date: 3/05/2020 1:32:00 PM
see previous comment

T Number: 11   Author: uqkconn5   Subject: Highlight   Date: 3/05/2020 1:33:09 PM
wording suggests they are evident in most seismic sections; is this correct?

> Author: uqkconn5   Subject: Sticky Note   Date: 6/05/2020 11:16:21 AM
> you note only a few examples, perhaps show in map view summary Figure (e.g. updated fig 4) other Calvert age faults

271   superbasins conspicuously thicken (Fig. 8a). This fault was evidently reactivated subsequent to formation
272   of the Calvert Superbasin and continued to be active for a limited time up to and including deposition of
273   the River and lowermost part of the Term supersequences. Thereafter, rocks of the Lawn Hill Platform were
274   buried beneath a post-rift blanket of near constant thickness that comprises the rest of the Term
275   Supersequence, along with an even thicker syntectonic sedimentary package made up of the Lawn, Wide
276   and possibly Doom supersequences (Figs. 3 & 8a). Sedimentary sequences making up this syntectonic
277   package were deposited contemporaneously with basin inversion and commonly thin over the crests of
278   antiformal folds developed in the hangingwall of the Riversleigh Fault and related shortcut thrust fault
279   developed in its footwall (Fig. 8a). Other thrusts, both synthetic and antithetic to the main fault and
280   hangingwall structures, likely developed during the same deformational event, taken here to be the Isan
281   Orogeny. The few large faults cutting upwards through these younger stratigraphic units from deeper levels
282   in the Isa or Calvert superbasins have steeper attitudes and do not appear to be associated with differential
283   thickening, indicating that they too may have formed during the Isa Orogeny or possibly an even younger
284   unrelated tectonic event. In any event, this phase of basin inversion is clearly in addition to the one that
285   predates deposition of the Isa Superbasin and whose main expression in the seismic data is a surface
286   onlapping the older Calvert Superbasin and beneath which rocks of the latter are visibly truncated.

Continuation of west-east seismic transect beneath South Nicholson Basin

288   Seismic data for the South Nicholson Basin have already been interpreted and published in their entirety
289   (Carr et al., 2019) and this paper is only concerned with parts of the seismic grid (Fig. 4) that connect with
290   existing lines to the east (Fig. 5) and likely share a common basin architecture with the immediately adjacent
291   Lawn Hill Platform. Particularly important in this context is the eastern end of seismic line 017GA-SN1
292   (Fig. 8b) which connects with the Century line (06GA-M2) and extends this west-east transect for some
293   considerable distance westwards (Fig. 4). Older basinal sequences in this region lie buried beneath the
294   South Nicholson Basin and younger cover rocks of Cambrian (Georgina Basin) and Mesozoic age
295   (Carpentaria Basin) and their stratigraphy has largely been determined through the extrapolation of
296   interpreted rock units (Gibson et al., 2017; Gibson et al., 2016) from the existing Century 06GA-M2 line
297   (Fig. 8a). The Isa and Calvert superbasins are both exposed at the surface along line 06GA-M2 but even so
298   interpretations of the subsurface geology along this line and 017GA-SN1 are not completely identical (cf
299   Gibson et al., 2017 and Carr et al., 2019), especially in regard to depth to basement and stratigraphic affinity
300   of the more deeply buried basinal sequences (see also FrogTech Geocience, 2018). Basement in this study
301   is thought to extend upwards to much higher crustal levels along line 017GA-SN1 than in either Carr et al
302   (2019) or FrogTech Geoscience (2018) and to be directly overlain by a commensurately thinner Leichhardt
303   Superbasin (Fig. 8b). Basin fill in the latter thins westward and, despite disruption by several low-angle
304   faults, can nevertheless be traced for some considerable distance across the seismic section before it pinches
305   out beneath rocks of the unconformably overlying Isa Superbasin and eventually terminates against a major
306   east-dipping normal fault (Fig. 8b). Sedimentary units in the overlying Isa Superbasin have a wedge-like
307   geometry and thicken into this same east-dipping structure which, like the similarly east-dipping
308   Riversleigh Fault, was evidently active at the time this superbasin was deposited (Fig. 8b). Both the River
309   and Term supersequences appear to be represented in this wedge as do correlatives of the Lawn, Wide and
310   Doom supersequences (Fig. 8b). As with their counterparts farther east, the Wide and Doom both thin over
311   the crest of an antiform developed in the hangingwall of the structure and likely constitute the syn-inversion
312   fraction of basin fill. By way of contrast, the River and Term supersequences making up the syn-rift
313   component of basin fill were deposited on an already inverted Leichhardt Superbasin as evidenced by the
314   abrupt truncation of the latter against the base of the overlying River Supersequence (Fig. 8b). Truncation
315   of the Leichhardt Superbasin beneath the Isa Superbasin is no less obvious in the hangingwalls of minor
316   and less intensely inverted faults elsewhere along line 017GA-SN1, lending strong support to the suggestion

Page: 7

317 made repeatedly in this paper that the two older basinal sequences had already undergone at least one phase
318 of uplift and erosion before deposition of the 1640 Ma River Supersequence. Much less clear from line
319 017GA-SN1, owing to the amount of basin inversion involved, ⓵ whether the Calvert Superbasin was ever
320 present and simply lost to erosion before sedimentation in the Isa Superbasin commenced. Many of the
321 more important east-dipping faults cut up section all the way to the base of the Isa Superbasin but have only
322 brought about a displacement of the older units and do not appear to be growth faults (Fig. 8b). These faults
323 are either of Calvert or Isa Basin age and possibly predate the much shallower dipping inversion structures
324 that offset all basinal units and continue all the way to the surface. These faults, and some of the steeper or
325 near vertical structures, appear to have been active subsequent to deposition of the South Nicholson Basin
326 which is mildly inverted across them.

North-south seismic sections orthogonal to 017GA-SN1

328 As a further check on basin geometry and structural architecture to the west of the Lawn Platform, two
329 sections (017GA-SN2 and 017GA-SN4) were selected for interpretation in a direction at a high angle or
330 orthogonal to 017GA-SN1 (Figs. 9a & 9b). With its NW-SE orientation, seismic line 017GA-SN2 cuts
331 across many of the same north or northwest-striking structures imaged in 017GA-SN1, most notably at
332 least one crustal-scale east- or ⓶ southeast-dipping fault that extends down to the MOHO (Fig. 9a) and is
333 manifestly the same structure responsible for much of the basin inversion observed in the Isa Superbasin.
334 The most obvious difference ⓷ between the two lines is the thick wedge-like basinal sequence imaged in its
335 hangingwall down to 7.0 seconds TWT. This sequence lies below the interpreted base of the Leichhardt
336 Superbasin in line 017GA-SN1 (Fig. 8b) and either represents an entirely separate older sedimentary
337 package or a continuation of the Leichhardt Superbasin downward to much deeper crustal levels than is
338 immediately apparent in the west-east oriented seismic section. In the absence of independent information,
339 it is not possible to discriminate between these two possibilities except to say that the same package is
340 evidently present in line 017GA-SN1 and corresponds to a zone of non-reflective crust which at a depth of
341 10 kilometres or more seems much too deep for the Leichhardt Superbasin (Fig. 9a) and shares none of the
342 higher amplitude reflectors common to other seismic lines through this basin elsewhere in the Mount Isa
343 region (e.g. 06GA-M3; Gibson et al., 2016). Several low-angle faults on lines 017GA-SN1 and 017GA-
344 SN2 also root downward into this zone (Figs. 8b & 9a) although neither they nor the surfaces bounding the
345 older sedimentary package are particularly conspicuous or maintain their individual character at depth.
346 Rather, all faults and surfaces appear to merge downward into one seismically bland and homogenised
347 region of middle crust more in keeping with expectations for metamorphic basement than the Leichhardt
348 Superbasin. Moreover, because line 017GA-SN1 is probably more closely aligned with lithological strike
349 in the older sedimentary package and its bounding surfaces, their apparent dip in this particular seismic
350 section is close to zero, resulting in surfaces whose traces are subhorizontal and parallel to each other. Only
351 along line 017GA-SN2 is the northern dip of this older package discernible.

352 As with the other two lines across the South Nicholson Basin, 017GA-SN4 (Fig. 9b) encompasses a
353 basement block ⓸ bounded on its northern side by a near vertical fault. This structure shares the same steep
354 dip as the fault developed along the northern flank of the Punjaub Structure (Fig. 6a) ⓹ and is possibly the
355 same structural feature. It too serves as the boundary to a wedge of southward-thickening sedimentary rocks
356 whose seismic character (short, high amplitude reflectors) is reminiscent of the along-strike River and Term
357 supersequences. These two sequences are consequently taken here to be part of the Isa Superbasin. They,
358 in turn, are overlain by a sedimentary sequence that likely includes the rest of the Isa Superbasin as well as
359 younger rocks of the South Nicholson and Georgina basins (Fig. 9b).

360 All older sequences are also recognised on the other side of the basement block (Fig. 9b) where they are
361 similarly buried beneath a thin veneer of younger sediments belonging to the South Nicholson and Georgina

Number: 1   Author: uqkconn5   Subject: Highlight   Date: 6/05/2020 11:18:15 AM

given the thickness of your interpreted wedge of Calvert in M2 why would you not expect Calvert extension on the other east-dipping fault on east margin of basement high on SN1? This fault was clearly active during Isa time even though it is not in an optimal orientation. Carr et al. (2019) interpret a westward thickening sequence beneath the Isa SB. Couldn't this be of Calvert age, consistent with the age dating of Carrara Range Gp?

Number: 2   Author: uqkconn5   Subject: Highlight   Date: 6/05/2020 11:19:07 AM

please label; does it have a name or link to other faults

Author: uqkconn5   Subject: Sticky Note   Date: 5/05/2020 12:54:32 PM

minor point but Moho isn't well defined in these lines; perhaps just say to 12-14 sec TWT, or lower crust

Number: 3   Author: uqkconn5   Subject: Highlight   Date: 3/05/2020 2:25:47 PM

which two? SN1 and SN2 or SN2 and SN4

Number: 4   Author: uqkconn5   Subject: Highlight   Date: 3/05/2020 2:33:31 PM

minor point but SN1 labelled as E-W so unclear;

Number: 5   Author: uqkconn5   Subject: Highlight   Date: 3/05/2020 2:40:42 PM

inconsistent with Figure 5 faults;

362 basins. basement is pene-planated beneath the Georgina Basin (Fig. 9b) although this likely represents only
363 the latest in a series of uplift and erosion events to have affected this lder cratonic block and its overlying
364 sedimentary sequences. Sedimentary sequences on the southern side of the basement block are consistently
365 thinner than their counterparts on the northern side (Fig. 9b) indicating that this block was probably being
366 actively uplifted and eroded before all of the Isa Superbasin had been deposited. Sediment shed from a
367 rising basement block could easily explain the northward-thickening wedge of sediment making up the
368 younger part of the Isa Superbasin identified at the northern end of the seismic section and is in keeping
369 with suggestions made elsewhere that sedimentation and basin inversion in the Isa Superbasin were coeval.
370 Significantly, as in lines 017GA-SN1 and 017GA-SN2, the Leichhardt Superbasin persists in highly
371 attenuated and truncated form, perceptibly thinning up section beneath the overlying Isa Superbasin (Fig.
372 9b).

Discussion

374 Extensional basins and their structural architecture both before and after inversion are now reasonably well
375 understood following numerous field studies combined with the results of numerical modelling and
376 sandbox experiments (Cooper et al., 1989; Hayward and Graham, 1989; McClay et al., 2002; McClay and
377 White, 1995; Turner and Williams, 2004). Emphasised in most of these studies is the strongly asymmetric
378 nature of basin fill and the consequences of shortening a sedimentary sequence whose individual unit
379 lengths are all different and increase upward from bottom to top of the section (Hayward and Graham,
380 1989; Lowell, 1995; Turner and Williams, 2004). The net result during shortening is development of an
381 equally asymmetric fold in the hangingwall of the original normal fault which may or may not have been
382 reactivated during the process. This hangingwall fold is one of the most distinctive features of basin
383 inversion and may be regarded as a diagnostic feature, particularly in cases where folding is enhanced by
384 the reactivation of coeval antithetic structures leading to the expulsion of basin fill in opposite directions.
385 Further enhancements of the basic inverted structure may occur where the normal fault locks up early and
386 strain is transferred to a footwall shortcut thrust or taken up by some other structure such as a strike-slip
387 fault (Dooley and McClay, 1997; McClay, 1995; McClay et al., 2002). These and other variations on
388 structural architecture developed during basin inversion (Martínez et al., 2012) are illustrated in Figure 10.
389 All examples are from inverted basins of Mesozoic or younger age but are clearly no less relevant in the
390 case of the older basins described here from northern Australia. Footwall shortcut thrusts have been
391 captured in several of the seismic sections but are conspicuously well developed in the footwalls of the
392 Century (06GA-M2) and Punjaub structures (Figs. 8a & 6b). However, by far the most common and widely
393 imaged structure is the hangingwall antiform (Fig. 10). Moreover, this same structural feature is evident in
394 all sections irrespective of whether they are oriented north-south or west-east, supporting suggestions made
395 elsewhere   that there has been more than one episode of basin inversion and that these were imposed on
396 basins that were originally orthogonal to one another. As such, basin inversion affords clues to basin
397 orientation before and after successive episodes of crustal shortening got underway and it is to this topic
398 that we now turn.

399 The Isa Superbasin is best known from the Lawn Hill Platform (Fig. 5) and has been previously interpreted
400 as a sag or foreland basin deformed during a subsequent north-south shortening event identified as the Isan
401 Orogeny (Betts et al., 2003; McConachie et al., 1993; McConachie and Dunster, 1996). More recently, an
402 extensional origin has been proposed for this same basin consistent with seismic data and general thickening
403 of sedimentary units like the River and Term supersequences into normal faults oriented ENE-WSW
404 (Bradshaw et al., 2018; Gorton and Troup, 2018). Antiformal closures developed in the Punjaub Structure
405 and periclinal folds exposed just to its south share the same ENE-WSW trend (Fig. 1b) and likely represent
406 basin inversion structures formed during the same north-south shortening event. However, as already
407 pointed out, the Punjaub Structure is not a simple structure and likely underwent limited folding before or

Number: 1   Author: uqkconn5   Subject: Highlight   Date: 3/05/2020 2:44:10 PM
Basement? or Mesoproterozoic and older units

Number: 2   Author: uqkconn5   Subject: Highlight   Date: 3/05/2020 2:44:51 PM
? older than what; or which cratonic block

> Author: uqkconn5   Subject: Sticky Note   Date: 3/05/2020 2:45:24 PM
> or are you just referring to the basement high?

Number: 3   Author: uqkconn5   Subject: Highlight   Date: 5/05/2020 4:01:30 PM
Punjaub fold is in HW of Tin Tank fault; no FW short cut thrusts are shown on 6a

> Author: uqkconn5   Subject: Sticky Note   Date: 5/05/2020 4:01:40 PM
> 6a rather than 6b

Number: 4   Author: uqkconn5   Subject: Highlight   Date: 3/05/2020 2:55:42 PM
alternatively compression may have been oblique to rift and resulted in inversion against ENE normal faults and steeper NW oblique slip faults

Number: 5   Author: uqkconn5   Subject: Highlight   Date: 3/05/2020 2:57:27 PM
not sure if they were the first but Bradshaw and Scott 1999 mapped the extensional structures

Number: 6   Author: uqkconn5   Subject: Highlight   Date: 3/05/2020 2:59:38 PM
did you discuss pre-River folding on this structure in text above?

408 subsequent to the start of deposition in the River and Term supersequences (Gibson et al., 2020). Along
409 with rocks of Calvert age in the core of the Punjaub Structure, these two sequences were deformed during
410 the 1650-1640 Ma Riversleigh Tectonic Event for which a NE-SW shortening direction has been proposed
411 (Gibson et al., 2020; Gibson et al., 2017). As such, shortening during the earlier stages of basin inversion
412 in the Punjaub Structure would have been approximately orthogonal to strike in the Calvert Superbasin and
413 its NW-SE basin-bounding normal faults. Seismic sections oriented parallel to this shortening direction
414 consistently show faults of Calvert age dipping eastwards (e.g. Riversleigh Fault) and several have
415 antiformal structures developed in their hangingwalls (Figs. 8a & 4b) in line with expectations that basin
416 geometry prior to inversion was highly asymmetric and had the form of a westward deepening half-graben.
417 Westward deepening of Calvert-age extensional basins on the Lawn Hill Platform is contrary to the results
418 of earlier geophysical modelling (Betts et al., 2004) indicating that half-graben of this age deepen
419 southwards towards normal faults with NE orientations essentially orthogonal to what is proposed here.
420 However, while faults with this orientation have been previously mapped (Hutton and Sweet, 1982) or have
421 been known to exist in the subsurface for a long time (Krassay et al., 2000a; Scott et al., 1998), it is debatable
422 that they are of Calvert age or exercised any significant control on depositional patterns during this phase
423 of basin formation. They share the same NE to ENE strike as normal faults in the Isa Superbasin and likely
424 belong to the same generation of structures that controlled deposition of the younger sedimentary basin.
425 Importantly, faults of this age exhibit increased amounts of throw southwards which would have been
426 accompanied by commensurate amounts of downward displacement in rocks of the underlying Calvert
427 Superbasin, as captured in seismic images (Fig. 6a) along line 91Bn-28-91Bn33 and the northern flank of
428 Punjaub Structure where the Loretta and Prize supersequences, along with older elements of the Isa
429 Superbasin, have been faulted downward by several kilometres relative to their counterparts across the crest
430 of the fold. This is the same stepped basin geometry picked up in the results of geophysical modelling for
431 the Lawn Hill Platform (Betts et al., 2004) and which, during later crustal shortening, would have produced
432 south-verging folds with the same NE axial direction orientation as periclinal folds now observed at Mount
433 Caroline and Ploughed Mountain (Fig. 1b). It further follows that the NW-SE extensional direction
434 previously proposed for the Calvert Superbasin more likely relates to the younger Isa Superbasin and only
435 came about because erosion across the Lawn Hill Platform during or subsequent to the Isa Orogeny
436 removed much of the younger basin infrastructure leaving behind only the inverted and once more deeply
437 buried rocks of the older basin.

438 West of the Lawn Hill Platform, crystalline basement lies at much shallower crustal depths and may even
439 have been exposed during deposition of the Georgina or South Nicholson basins, forming one or more
440 structural highs over the top of which there is a conspicuous thinning or draping of the younger cover rocks
441 (Fig. 9b). The older Paleoproterozoic-early Mesoproterozoic sequences are similarly notably thinner over
442 basement in this region and the Calvert Superbasin may be entirely missing (Figs. 8b & 9b), either because
443 it was never deposited or was removed by erosion during uplift accompanying the Riversleigh Tectonic
444 Event. The River Supersequence consequently directly overlies on a truncated and westward thinning older
445 sequence taken here to be the Leichhardt Superbasin based on continuity with line 06GA-M2 (Fig. 8a) for
446 which a stratigraphic interpretation has already been published. As with line 06GA-M2 (Fig. 8a), an angular
447 unconformity separates the two sequences (e.g. Fig. 8b), and the Leichhardt Superbasin had likely already
448 been inverted before the River Supersequence was laid down. In keeping with this suggestion, the older
449 sequence has locally been completely eroded away so that the River Supersequence rests directly on older
450 crystalline basement (Fig. 8b). Moreover, even though a significant amount of this uplift and erosion may
451 have been accommodated on reactivated older normal faults, the dominant structures in the seismic images
452 are sub-vertical to steeply dipping and abruptly truncate stratigraphy not only in basement but thick basinal
453 sequences developed in their footwalls. These footwall sequences encompass most if not all units of the Isa
454 Superbasin (Figs. 8b & 9b), pointing to either a considerable amount of downward throw to the north on

Number: 1   Author: uqkconn5   Subject: Highlight   Date: 3/05/2020 3:00:18 PM

Number: 2   Author: uqkconn5   Subject: Highlight   Date: 3/05/2020 3:06:17 PM

no - River and Term post date Riversleigh Event on Figure 3 and this has been my understanding based on documented evidence from outcrop and seismic.

I have flagged elsewhere that I am confused by your max age for River on Fig 3 as published age dating (i.e. on tuffs not MDA) suggest it is older than ca 1540 Ma; please clarify this as well as your constraints on Riversleigh Event and its timing relative to River deposition. Are you suggesting River is syn-inversion?

Number: 3   Author: uqkconn5   Subject: Highlight   Date: 5/05/2020 4:07:41 PM

Figure 8b does not show a Calvert basin; if the east dipping faults are Calvert age why isn't a Calvert depocentre present

Number: 4   Author: uqkconn5   Subject: Highlight   Date: 5/05/2020 4:06:21 PM

Number: 5   Author: uqkconn5   Subject: Highlight   Date: 5/05/2020 4:06:20 PM

Number: 6   Author: uqkconn5   Subject: Highlight   Date: 5/05/2020 4:10:47 PM

I would expect the steep NE or ENE faults that show a long lived history to reactivate as oblique-slip or "transfer" faults during NE-SW extension

Number: 7   Author: uqkconn5   Subject: Highlight   Date: 3/05/2020 3:30:38 PM

are there any outcrop examples where we see River on Leichhardt?

Number: 8   Author: uqkconn5   Subject: Highlight   Date: 3/05/2020 3:39:33 PM

which age? I'm not certain which part of seismic line you are discussing here.

     Author: uqkconn5   Subject: Sticky Note   Date: 3/05/2020 3:42:15 PM
     its evident in 9b but not obvious in 8b

Number: 9   Author: uqkconn5   Subject: Highlight   Date: 3/05/2020 3:41:04 PM

Number: 10   Author: uqkconn5   Subject: Highlight   Date: 3/05/2020 3:42:27 PM

455 these structures or an equally significant amount of strike-slip displacement. The latter is thought more
456 likely here consistent with the scale and abruptness of truncation and the observation that the faults overall
457 have the character of flower-like structures (Fig. 9b). Either way, it is difficult to avoid the conclusion that
458 basement uplift on these subvertical faults occurred late as these structures displace all units in the Isa
459 Superbasin and cut up-section all the way to the base of the Cambrian. Faults with similarly steep attitudes
460 and character are also evident in north-south oriented seismic sections (Fig. 6) for the northern Lawn Hill
461 Platform (e.g. 91Bn-28; 91Bn-33) and likely belong to the same generation of strike-slip faults.
462 Significantly, they share the same E to ENE strike and were possibly initiated on older structures dating
463 back to formation of the Isa Superbasin into which they root downward (Fig. 6a).

464 **Basin inversion and implications for Pb-Zn mineralisation**

465 As revealed in seismic sections oriented orthogonal to one another, basin inversion in the north Australian
466 Paleoproterozoic-Mesoproterozoic sequences occurred on more than one occasion and gave rise to a
467 structural architecture not unlike that recorded in basins of much younger age such as the Irish and North
468 seas and North Atlantic petroleum province more generally. No less important in this context are the results
469 of past and recent drilling confirming that northern Australia is prospective for oil and gas (Gorton and
470 Troup, 2018; Jackson et al., 1986; McConachie et al., 1993) thereby simply justifying the case for such
471 comparisons. Further warranting such comparisons is the work of Broadbent et al (1998) who reported that
472 rocks hosting the Century Pb-Zn deposit (Wide Supersequence) are bituminous, since corroborated by more
473 recent studies showing this and other parts of the Isa Superbasin to contain exceptionally high levels of
474 total organic carbon (Gorton and Troup, 2018; Jarrett et al., 2018). Host rocks to the Century deposit include
475 carbonaceous siltstones and dolostones whose carbon content is thought to have transformed these rocks
476 into a suitable reductant during the passage of more oxidising metal-bearing fluids from below. On
477 encountering this reducing environment, a number of catalysed redox reactions ensued during the course
478 of which metal sulphides were precipitated (Broadbent et al., 1998; see also Huston et al., 2006). Other Pb-
479 Zn deposits across the region, including Mount Isa, are thought to have formed through the same process
480 although mineralisation is typically determined to have occurred during basin formation with the metal-
481 bearing fluids transported upwards along normal faults active at the time of sedimentary deposition. Mineral
482 exploration has accordingly often been directed towards the identification of structures and sedimentary
483 sequences formed during the course of basin formation as opposed to those that may have formed during
484 later basin inversion.

485 However, as is now evident from recent seismic interpretations of line 06GA-M2 (Gibson et al., 2017;
486 Gibson et al., 2016), the carbonaceous rocks hosting Century belong to the syn-inversion fraction of basin
487 fill and were deposited at a time of crustal shortening accompanying onset of the Isan Orogeny. There is no
488 evidence that this shortening was accompanied by reactivation of the basin-bounding structure. Instead, as
489 with many normal faults, the Riversleigh Fault dipped too steeply to be easily reactivated and strain was
490 taken up on a footwall shortcut thrust; it rather than the Riversleigh Fault would have served as the better
491 fluid conduit. Interestingly, the Termite Range Fault has some of the fine attributes as a footwall shortcut
492 thrust and is widely believed (Broadbent et al., 1998; Yang and Radulescu, 2006) to have been the main
493 fluid conduit for the Century deposit which lies either above or in a minor offshoot immediately adjacent
494 to the master structure. No less importantly, mineralisation is transgressive with respect to stratigraphy and
495 occurred through replacement processes, consistent with the 1575 Ma age reported for this deposit (Carr et
496 al., 2004). This is long after the start of crustal shortening and probable concomitant expulsion of
497 hydrocarbons to higher stratigraphic levels where they would have pooled or been trapped in structures
498 formed during inversion. Alternatively, basin fill at these levels may already have been sufficiently enriched
499 in carbon during the depositional stage. Irrespective of such uncertainties, the metal-bearing fluids migrated
500 into the same structures where they were reduced and forced to give up their Pb and Zn. It seems further

Number: 1   Author: uqkconn5 Subject: Highlight Date: 3/05/2020 3:46:14 PM

Little Ranges Fault? or the Steep S dipping fault? or both? It is not clear. You previously suggested Little Ranges fault could link to fault controlling Punjaub structure

Number: 2   Author: uqkconn5 Subject: Highlight Date: 6/05/2020 11:25:25 AM

Are you suggesting that the steep basement faults that penetrate to 9-11 sec TWT (i.e. Fig 9b) formed during late Isa SB inversion at the same time as the smaller scale strike slip faults that occur within Isa SB and link into normal faults that accommodated Isa extension. Aren't the deep penetrating faults more likely to be older and simply reactivated?
You previously suggested there was older movement associated with the LRF and /or the other steep fault on Fig 9b

Number: 3   Author: uqkconn5 Subject: Highlight Date: 3/05/2020 3:47:24 PM

Number: 4   Author: uqkconn5 Subject: Highlight Date: 3/05/2020 3:47:30 PM

Number: 5   Author: uqkconn5 Subject: Highlight Date: 3/05/2020 3:55:58 PM

see previous comments; I don't understand this emphasis

Number: 6   Author: uqkconn5 Subject: Highlight Date: 5/05/2020 4:15:52 PM

?? confusing
carbon content contributed to reducing environment of the host rocks, but it did not "transform" the rocks; carbon content results from depositional setting (in many of the documented examples);

Number: 7   Author: uqkconn5 Subject: Highlight Date: 3/05/2020 4:01:42 PM

wording suggests metal bearing fluids provided carbon which "transformed" the host rocks

Number: 8   Author: uqkconn5 Subject: Highlight Date: 5/05/2020 4:17:29 PM

although mineralisation is younger

Number: 9   Author: uqkconn5 Subject: Highlight Date: 5/05/2020 4:18:17 PM

depends on shortening direction relative to the fault; i.e. if it was ~N-S then reactivation is more likely on a steeper NNW fault than during ~E-W compression

Number: 10   Author: uqkconn5 Subject: Highlight Date: 3/05/2020 4:04:56 PM

please label on seismic section to highlight

Number: 11   Author: uqkconn5 Subject: Highlight Date: 3/05/2020 4:17:31 PM

are you suggesting it is a FW shortcut?
Why did it reactivate if Riversleigh didn't - they have a similar dip in your interpretation.

Number: 12   Author: uqkconn5 Subject: Highlight Date: 5/05/2020 4:19:35 PM

is there any evidence on timing? Given the variations in thickness of the basin sequences it is likely to have varied.

Number: 13   Author: uqkconn5 Subject: Highlight Date: 5/05/2020 4:19:24 PM

Number: 14   Author: uqkconn5 Subject: Highlight Date: 3/05/2020 4:27:42 PM

are there any documented structures that trapped migrating hydrocarbons

> Author: uqkconn5 Subject: Sticky Note   Date: 3/05/2020 4:28:21 PM
> if you are talking in general terms; its good to make this clear to the reader

Number: 15   Author: uqkconn5 Subject: Highlight Date: 3/05/2020 4:29:11 PM

yes this is well documented for many units

Number: 16   Author: uqkconn5 Subject: Highlight Date: 3/05/2020 4:32:34 PM

please be specific about where this is documented; i.e. migration of Pb-Zn bearing fluids into structures where hydrocarbons had previously migrated, as opposed to Pb-Zn bearing fluids migrating into zones / structures where high TOC occurred during deposition

likely if the analogy with the petroleum system has any validity that a significant amount of this metal-bearing fluid found its way into the same type of hangingwall structures that are so prospective of oil and gas in the younger inverted basins of the North Atlantic petroleum province. If this is indeed the case, then exploration strategies for sediment-hosted Pb-Zn mineralisation may have to change with exploratory drilling redirected away from former normal faults towards potential structural traps in their hangingwalls.

Acknowledgements

For the invitation and opportunity to contribute to the special anniversary volume on basin inversion we thank editors, professors Jonas Kley and Piotr Krzywiec. Thanks also to Teck Resources Australia and Pursuit Minerals for permission to publish our interpretation of the Punjaub Structure. Figure 2 was produced on our behalf by Dr Ian Withnall, Geological Survey of Queensland. Seismic reflection data on which this paper depends are available online from their respective data repositories: (Geoscience Australia eCat: http://pid.geoscience.gov.au/dataset/ga/69674) and Queensland Geological Survey Burketown survey https://qdexdata.dnrme.qld.gov.au/GDP/Results?minLong=137.72&maxLong=142.46&minLat=26.39999 99992479&maxLat=16.124999999496).

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what about other features highlighted in figure 10; e.g. FW shortcut thrust to Riversleigh F as discussed above

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753

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Figure Captions

Figure 1. (a) Simplified geological map for northern Australia showing principal tectono-morphological elements and Pb-Zn mineral deposits (after Jackson et al., 2000). (b) More detailed geological map of periclinal folds developed in inverted stratigraphy of the Isa Superbasin on the Lawn Hill Platform east of Century Mine and seismic reflection lines 06GA-M1 and 06GA-M2 along which these structures are imaged. Figure reproduced with permission under the Creative Commons Attribution 4.0 International Licence: http://creativecommons.org/licenses/by/4.0/legalcode. © Commonwealth of Australia (Geoscience Australia) 2020.

Figure 2. Map showing presently defined limits of outcropping Leichhardt, Calvert and Isa superbasins across the Mount Isa region. Seismic reflection data indicate that all three basins are variably preserved in the subsurface geology beneath the South Nicholson and Georgina basins and continue northwards into the McArthur Basin and Batten Trough (see Carr et al., 2019). Reproduced with permission: Licensed CC BY version 4.0 © State of Queensland, 2020.

Figure 3. Simplified stratigraphic column for Mount Isa region and neighbouring southern McArthur Basin showing three-fold subdivision into Leichhardt, Calvert and Isa superbasins but different interpretations of basin history and tectonic evolution (Betts et al., 2003; Betts and Lister, 2001; Gibson et al., 2016; Southgate et al., 2000a). The Carrara Range Group is shown as part of the lower Tawallah Group and a correlative of the Leichhardt Superbasin based on revised mapping (Rawlings et al., 2008) and recently published geochronological data (Kositcin and Carson, 2019) for the McArthur Basin.

Figure 4 Superposition of South Nicholson seismic grid over an anomalously deep gravity low bounded by the Carrara Range (gravity high) to the north of line 17GA-SN1 (after Carr et al., 2019) requiring the presence of less dense rocks at depth such as an unusually thick sedimentary basin and/or large felsic igneous body of batholithic proportions such as observed farther south in the Sybella Granite. Figure reproduced with permission under the Creative Commons Attribution 4.0 International Licence: http://creativecommons.org/licenses/by/4.0/legalcode. © Commonwealth of Australia (Geoscience Australia) 2020.

Figure 5. Basin and basement architecture for northern Lawn Hill Platform showing main depocentres and fault trends for Isa Superbasin (after Gorton and Troup, 2018). Also shown are various industry seismic survey lines from 1994 (Comalco) and 2011 (Teck Resources) across the Isa Superbasin and adjacent Punjuab Structure (P). Yellow lines are for composite image presented in Figures 6-7. Note compartmentalisation of depocentres brought about by interference between the ENE and NW-trending faults; latter are of Calvert age and include older normal faults (e.g. Riversleigh Fault) reactivated as strike-slip structures during crustal extension accompanying formation of the Isa Superbasin. Reproduced with permission: Licensed CC BY version 4.0 © State of Queensland, 2020.

Figure 6. North-south oriented transect across northern Lawn Hill Platform made up of selected industry and government seismic sections (Fig. 5) showing predominance of north-dipping normal faults on which there has been successive episodes of basin inversion, leaving behind a legacy of fault reactivation and periclinal folding in (a) Punjaub Structure and (b) Mount Caroline and Ploughed Mountain (after Gibson et al., 2017; 2020). Note thinning of River and Term supersequences northward through onlap in (a); the underlying Loretta Supersequence similarly thins northward but is bounded top and bottom by truncated surfaces thought to reflect considerable loss of stratigraphic section by uplift and erosion accompanying the 1650-1640 Ma Riversleigh Tectonic Event. Sedimentary patterns point to growth faulting on north-dipping structures during deposition of the Isa, but not underlying Calvert Superbasin whose sequences are merely offset. Bluewater, Boga and Tin Tank Fault names adopted from Bradshaw et al (2018) and industry

Number: 1   Author: uqkconn5   Subject: Highlight   Date: 5/05/2020 12:27:40 PM
Lawn Hill region

Number: 2   Author: uqkconn5   Subject: Highlight   Date: 5/05/2020 12:28:27 PM
not shown

Number: 3   Author: uqkconn5   Subject: Highlight   Date: 5/05/2020 12:31:34 PM
are you implying depth to basement? I would instead describe the negative gravity anomaly as having a high amplitude.

Number: 4   Author: uqkconn5   Subject: Highlight   Date: 5/05/2020 12:31:50 PM
positive gravity anomaly

Number: 5   Author: uqkconn5   Subject: Sticky Note   Date: 5/05/2020 4:30:01 PM
Which gravity dataset is shown in the image? Bouguer or something else?

Number: 6   Author: uqkconn5   Subject: Highlight   Date: 5/05/2020 12:32:57 PM
need to explain what is depicted in the background image; and add Z scale

Number: 7   Author: uqkconn5   Subject: Highlight   Date: 5/05/2020 12:33:52 PM
cant see a P

Number: 8   Author: uqkconn5   Subject: Highlight   Date: 5/05/2020 12:34:49 PM
and location of fig 8 and 9

Number: 9   Author: uqkconn5   Subject: Highlight   Date: 5/05/2020 12:35:44 PM
show on image

Number: 10   Author: uqkconn5   Subject: Highlight   Date: 5/05/2020 12:37:09 PM
why are there thickness changes?

798   (Pursuit Minerals, 2017). In (b) the older sequence had already been folded before the River Supersequence
799   was deposited as evidenced by thinning of the latter over the crests of folds developed in the Calvert
800   Superbasin at deeper levels beneath Mount Caroline. The Calvert Superbasin is in turn separated by an
801   angular unconformity from an even older underlying sequence inferred (Gibson et al., 2017; Gibson et al.,
802   2016) to be the Leichhardt Superbasin. Colour coding is same as Figure 3.

803   Figure 7. West-east oriented seismic transects through northern Lawn Hill Platform. Westward thickening
804   of Calvert-age sedimentary units in both (a) and (b) is consistent with growth faulting on east-dipping
805   normal faults which have since been variably reactivated (Isa Orogeny). Conversely, no such growth is
806   evident in the overlying Isa Superbasin whose lithological strike and inversion structures are essentially
807   parallel to the line of section. These units still thicken into the centre of the Isa Superbasin but in a direction
808   orthogonal to normal faults active during its deposition. Such faults, if imaged, would be expected to be
809   flat-lying or have very shallow dips parallel or subparallel to bedding in both sections rending their
810   recognition very difficult. Some of the disruption to bedding in (b) along line 90Bn-10 may be due to such
811   faults but overall the most obvious structural feature in the section is the broad arching and folding of
812   stratigraphy in the middle of the section consistent with imaging of an inversion fold in longitudinal cross-
813   section.

814   Figure 8. West-east oriented section through (a) Century Mine (06GA-M2) and (b) its western continuation
815   (017GA-SN1) across the South Nicholson Basin and Carrara Sub-basin (Carr et al., 2019). The older basins
816   of Paleo- Mesoproterozoic age are nowhere exposed along line 017GA-SN1 and the only constraint
817   presently available on their stratigraphy and structural architecture west of the Lawn Hill Platform comes
818   from contiguity with the Century line 06GA-M2 for which an interpretation has already been presented
819   (Gibson et al., 2017; Gibson et al., 2016). Particularly noteworthy in line 017GA-SN1 is the westward
820   thinning of the older sequence beneath the Isa Superbsin, and inversion of it and the Isa Superbasin above
821   a major east-dipping structure that also brought basement to much shallower crustal levels. This older
822   sequence is thought to be of Leichhardt age and has been visibly truncated around the crest of the inversion
823   structure such that the overlying Isa supersequences comes to rest directly on crystalline basement. As in
824   (a), most if not all units of the Isa Superbasin, including the syn-inversion fraction (Lawn, Wide and Doom
825   supersequences), appear to be preserved on the western flank of this inversion structure. An uplifted
826   basement horst block across which basin polarity changes is evident at the western end of the seismic
827   section. The South Nicholson Basin is thinner and shown lying higher than in other recent interpretations
828   (Carr et al., 2019; Geoscience, 2018).

829   Figure 9. North-south oriented seismic sections west of Lawn Hill Platform showing shallow crystalline
830   basement and same basement-rooted inversion structure. Note major basement structure in (a) that cuts
831   downward all the way to the MOHO is probably the same basement structure imaged in (b) and over which
832   all older sedimentary basins have been eroded so that rocks of Cambrian age (Georgina Basin) directly
833   overlie basement (017GA-SN4). Rocks of the South Nicholson have similarly been removed for the crest
834   of this basement block in 017GA-SN4 and, together with rocks of the Isa Superbasin, increase in thickness
835   northwards. The Isa Superbasin is abruptly truncated by the basement structures and other subvertical
836   structures suggestive of a flower structure and late-stage onset of strike-slip faulting at or before deposition
837   of Cambrian Georgina Basin.

838   Figure 10. Basin inversion and resulting styles of structural architecture to be anticipated during crustal
839   shortening (after Martinez et al, 2012; McClay, 1995): (a) early normal fault; (b) harpoon structure from
840   partially inverted normal fault; (c) buttressing; (d) hangingwall is faulted forming hangingwall shortcut; (e)
841   footwall shortcut thrust; (f) folding and truncation of normal fault by younger thrust; (g) thrust ramp above
842   normal fault.

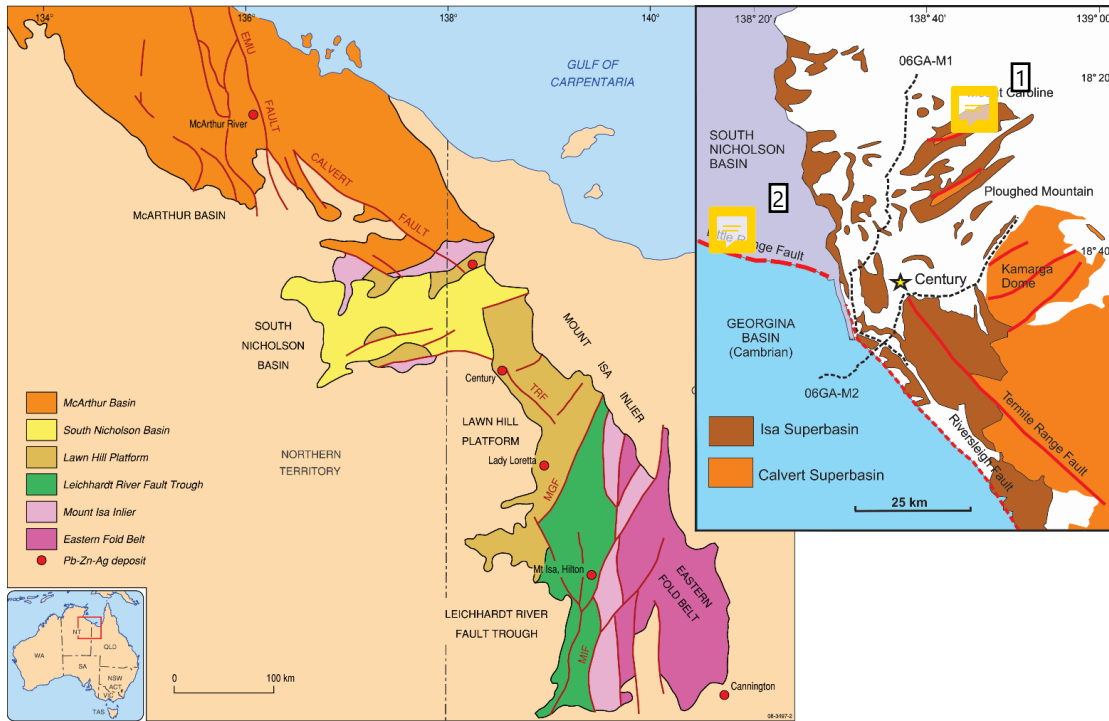
Number: 1   Author: uqkconn5 Subject: Highlight Date: 5/05/2020 12:39:10 PM
SW-NE and W-E

Number: 2   Author: uqkconn5 Subject: Highlight Date: 5/05/2020 12:38:40 PM

Number: 3   Author: uqkconn5 Subject: Highlight Date: 5/05/2020 12:41:24 PM
why do these faults not reactivate when the Riversleigh does?

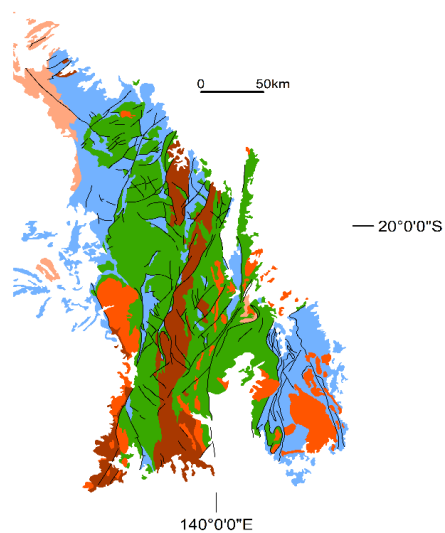
Number: 4   Author: uqkconn5 Subject: Highlight Date: 5/05/2020 12:48:30 PM
i don't think SNB units are interpreted on images shown in the report

Number: 5   Author: uqkconn5 Subject: Highlight Date: 5/05/2020 12:49:37 PM
same as what

Number: 6   Author: uqkconn5 Subject: Highlight Date: 5/05/2020 12:50:32 PM
indicate which one

843

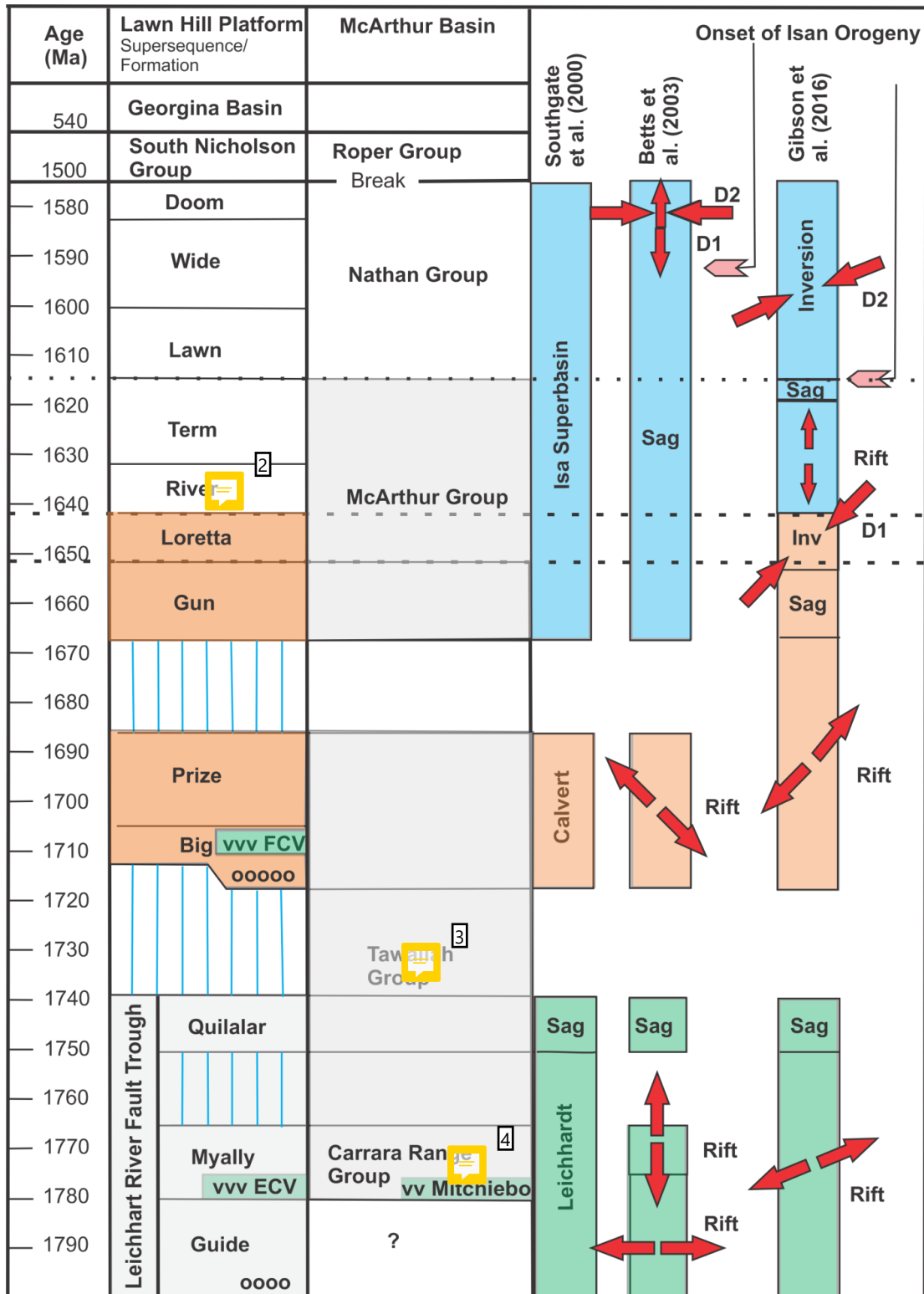
844 Figure 1

Number: 1   Author: uqkconn5   Subject: Sticky Note   Date: 5/05/2020 12:55:15 PM
what are the red lines that are not labelled?

Number: 2   Author: uqkconn5   Subject: Sticky Note   Date: 5/05/2020 12:56:23 PM
is this interpretation of LRF consistent with yours

845

846   Figure 2

Number: 1   Author: uqkconn5   Subject: Sticky Note   Date: 5/05/2020 4:31:53 PM
there is a bit of repetition of location figures. Perhaps combine this with Figure 1?

Author: uqkconn5   Subject: Sticky Note   Date: 5/05/2020 4:32:19 PM
And add a box to show location of figure 4 and 5

Number: 1   Author: uqkconn5   Subject: Sticky Note   Date: 1/05/2020 3:33:59 PM

Please show Pb-Zn hosts and age constraints for Pb-Zn orebodies

Number: 2   Author: uqkconn5   Subject: Sticky Note   Date: 6/05/2020 11:30:48 AM

Age constraints indicate River SS includes units dated at 1647 and 1648 Ma. Are there new age constraints?

Number: 3   Author: uqkconn5   Subject: Sticky Note   Date: 1/05/2020 3:52:05 PM

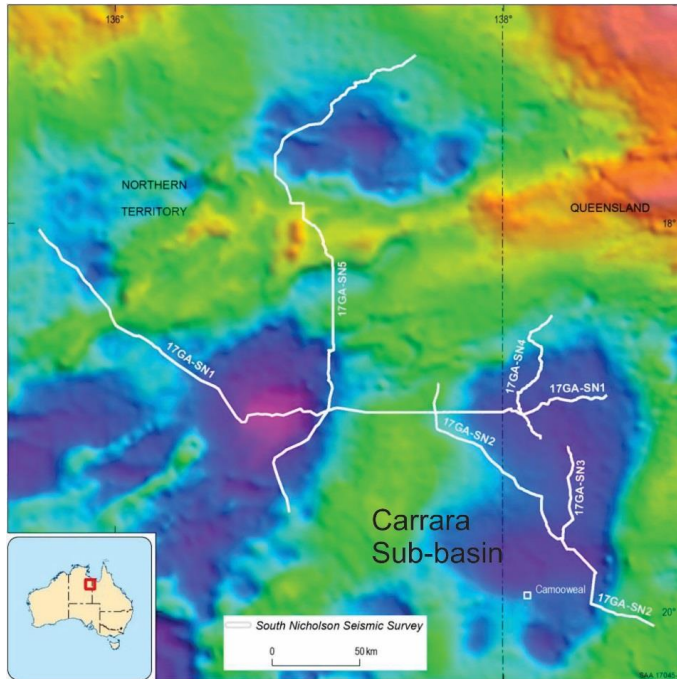
age range of Tawallah is unclear in this figure

Number: 4   Author: uqkconn5   Subject: Sticky Note   Date: 1/05/2020 3:51:22 PM

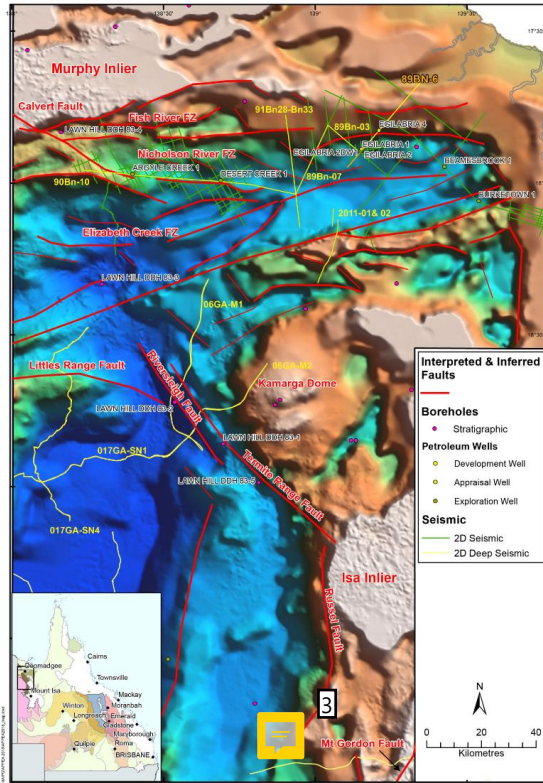
Carrara Range is younger; Carson et al 2020

     Author: uqkconn5   Subject: Sticky Note   Date: 6/05/2020 11:31:52 AM

It at least includes younger units even if Mitchiebo is not constrained older.

848   Figure 3

849

850   Figure 4

Number: 1   Author: uqkconn5   Subject: Sticky Note   Date: 5/05/2020 4:33:36 PM
I recommend combining figures 4 and 5 to show the location of seismic included in this study

851

852   Figure 5

Number: 1   Author: uqkconn5   Subject: Sticky Note   Date: 3/05/2020 2:39:55 PM

would be better to show a map with your fault interpretation; specifically one that shows the extent of the SN seismic lines depicted in the other images; if you don't agree with the depth to basement I wouldn't use the image.

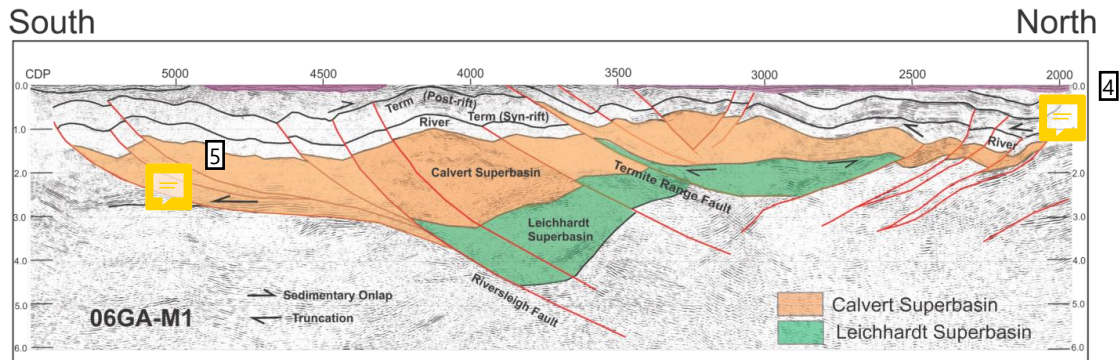
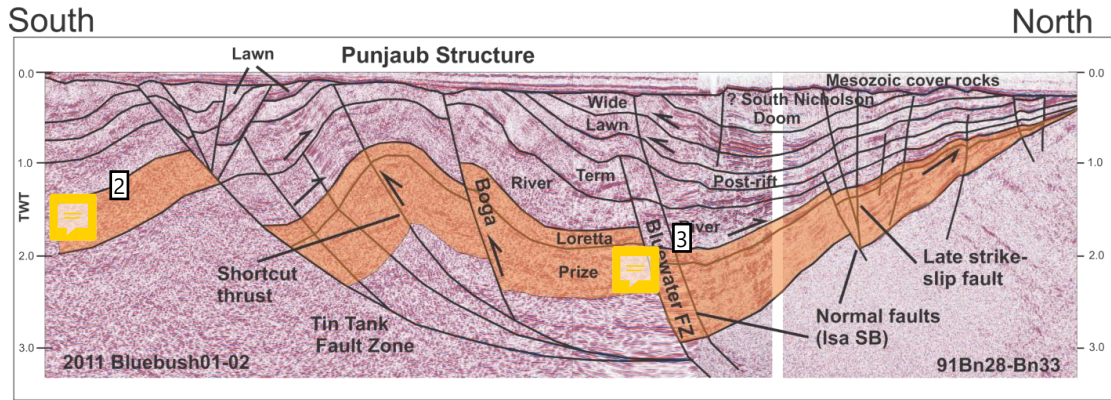
Author: uqkconn5   Subject: Sticky Note   Date: 5/05/2020 4:34:14 PM

You can use gravity instead and detail figure 4.

Number: 2   Author: uqkconn5   Subject: Sticky Note   Date: 3/05/2020 3:26:51 PM

If Riversleigh and Termite Range faults are listric normal faults as shown in the seismic interpretations; why are they straight in plan view? This is not typical for listric normal faults.

Number: 3   Author: uqkconn5   Subject: Sticky Note   Date: 5/05/2020 4:28:44 PM

SEEBASE image needs a Z scale

853

854   Figure 6

Number: 1   Author: uqkconn5   Subject: Sticky Note   Date: 1/05/2020 4:56:43 PM

please indicate extent of each line and where the overlap occurs

---

Number: 2   Author: uqkconn5   Subject: Sticky Note   Date: 1/05/2020 5:00:39 PM

Calvert SB as shown has significant thickness changes across Bluewater, Boga and Tin Tank faults

---

Number: 3   Author: uqkconn5   Subject: Sticky Note   Date: 3/05/2020 6:16:46 PM

are Gun and Big absent in this area?

Number: 4   Author: uqkconn5   Subject: Sticky Note   Date: 1/05/2020 5:16:38 PM

an enlarged figure showing the key onlap relationships would be helpful

---

Number: 5   Author: uqkconn5   Subject: Sticky Note   Date: 3/05/2020 3:19:48 PM

Interpretation of Leichhardt and Calvert SB and their relationship to the Riversleigh Fault differs on M1 and M2; the interpretation does not appear to be consistent or match at the intersection of the lines (but it is difficult to judge for certain from the location map).

Number: 6   Author: uqkconn5   Subject: Sticky Note   Date: 5/05/2020 12:58:10 PM

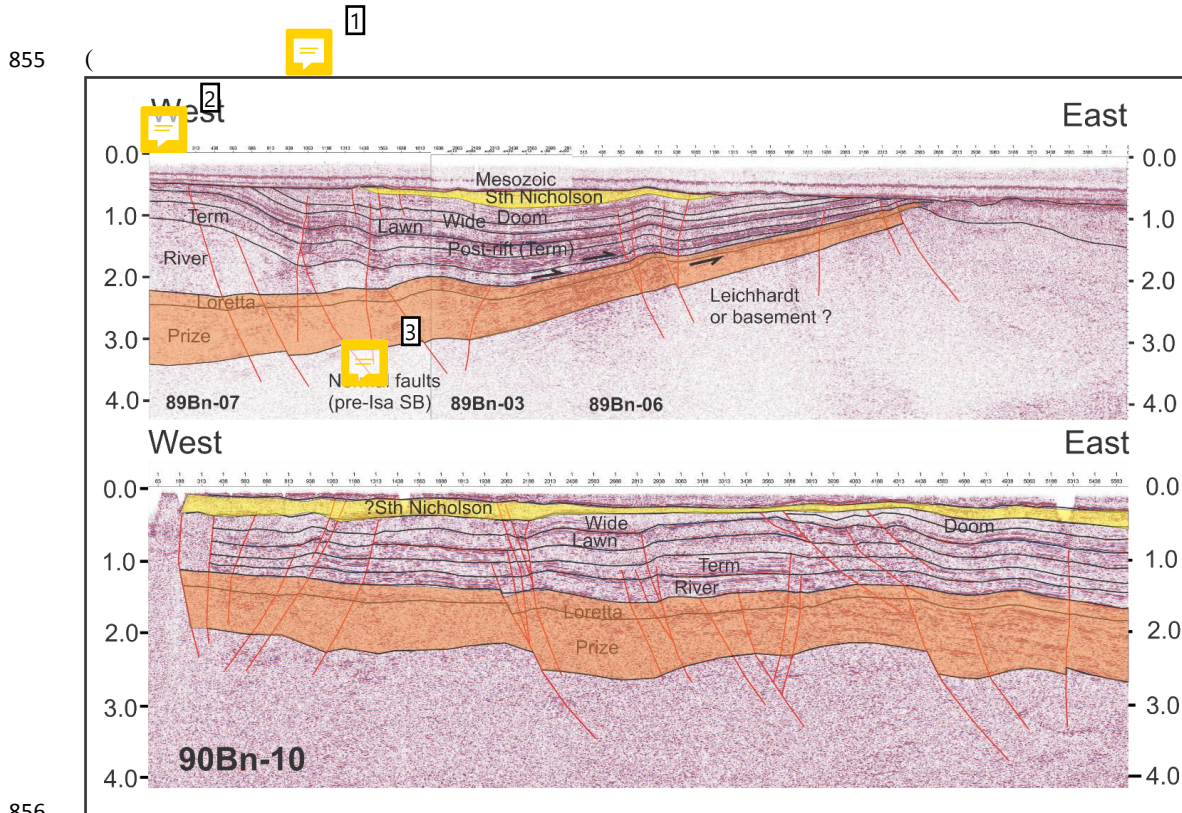
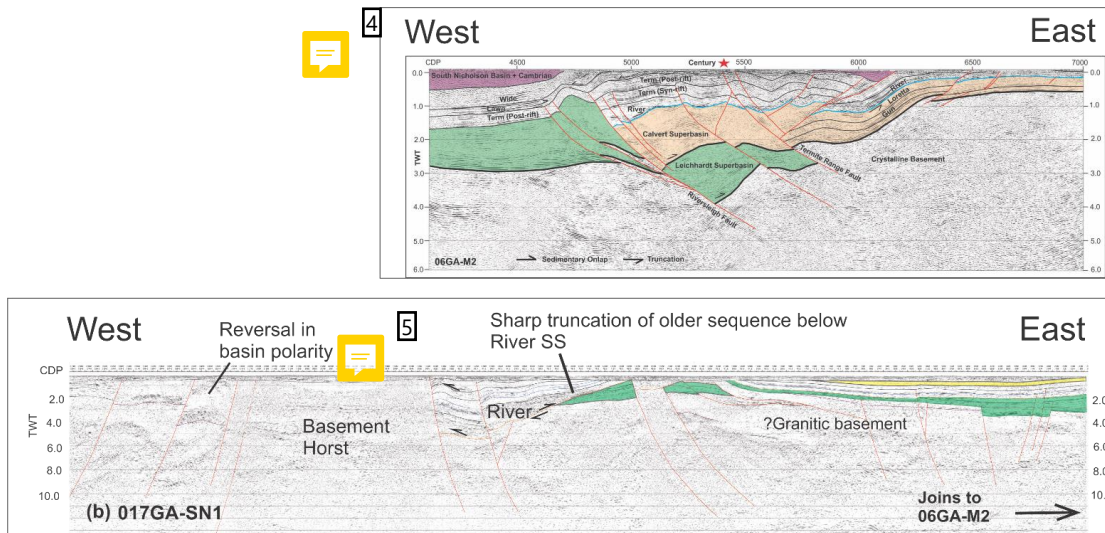
please indicate location of intersection seismic lines on each Figure; i.e. where does M2 intersect M1 and vice versa; does BN10 of fig 7b intersect BN28-33?
And same for the SN lines

855

856

857   Figure 7

858

859

860   Figure 8

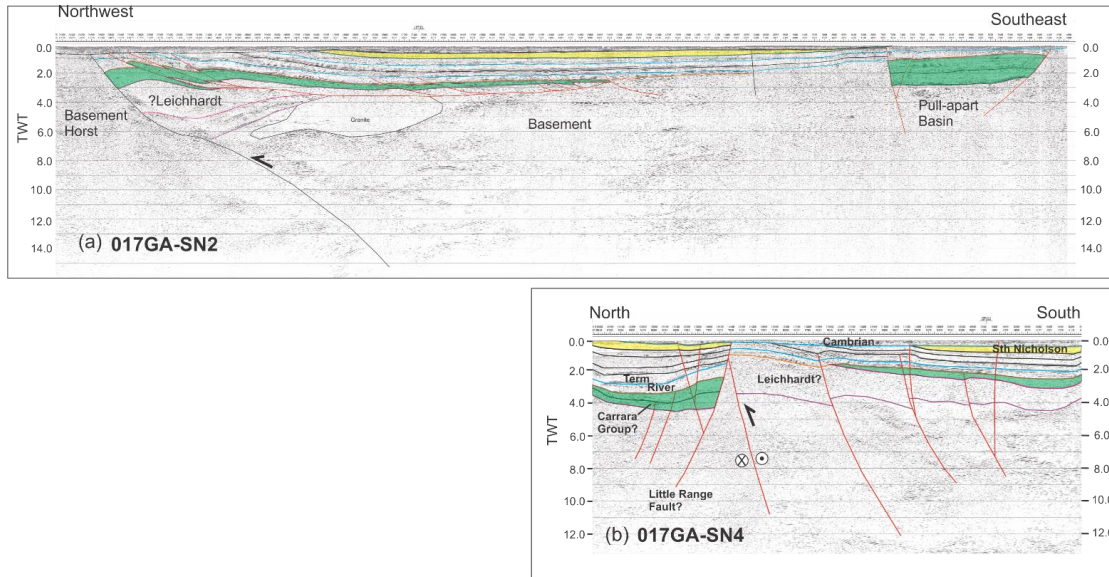
Number: 1   Author: uqkconn5   Subject: Sticky Note   Date: 3/05/2020 6:17:50 PM
are Gun and Big absent on these lines?

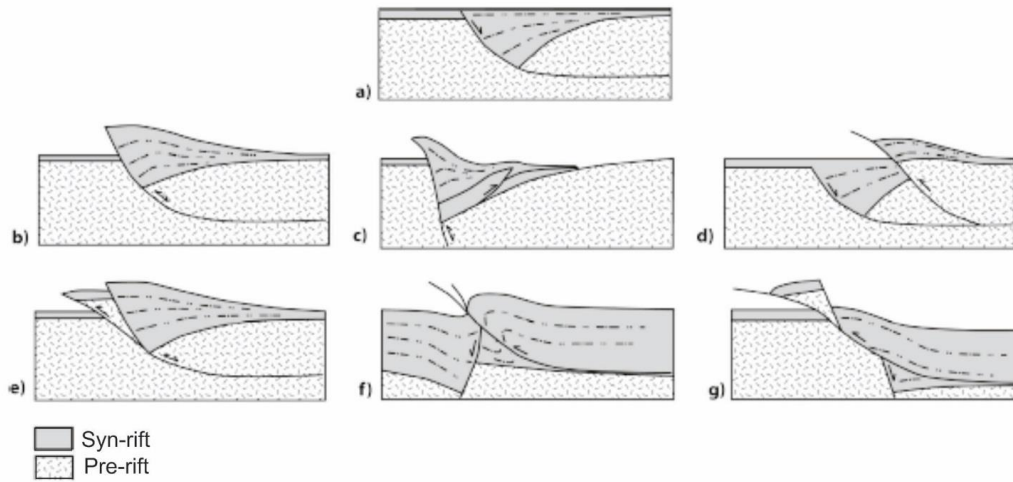
Number: 2   Author: uqkconn5   Subject: Sticky Note   Date: 3/05/2020 6:22:47 PM
SW - NE orientation

Number: 3   Author: uqkconn5   Subject: Sticky Note   Date: 5/05/2020 12:58:58 PM
can the strike of these pre Isa faults be confirmed by linking the interpretation to other lines; why don't they reactivate when RIversleigh does

Number: 4   Author: uqkconn5   Subject: Sticky Note   Date: 3/05/2020 6:22:00 PM
please indicate extent of overlap with SN1

Number: 5   Author: uqkconn5   Subject: Sticky Note   Date: 5/05/2020 12:44:17 PM
should be some SNB over basement high

Number: 6   Author: uqkconn5   Subject: Sticky Note   Date: 5/05/2020 1:00:13 PM
given these two lines overlap, it would be nice to have the same vertical scale

861

862 Figure 9

863

864 Figure 10

This page contains no comments