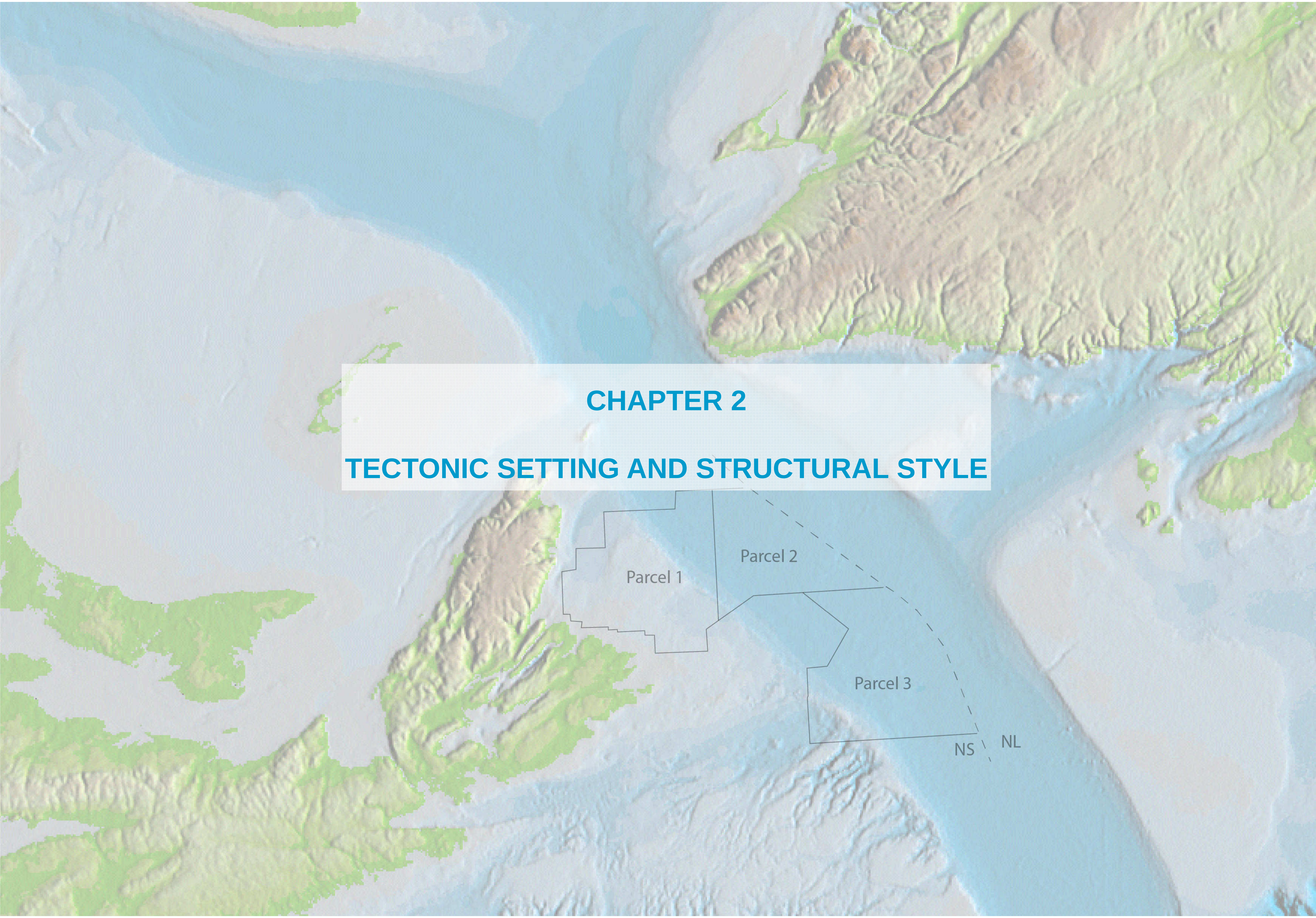
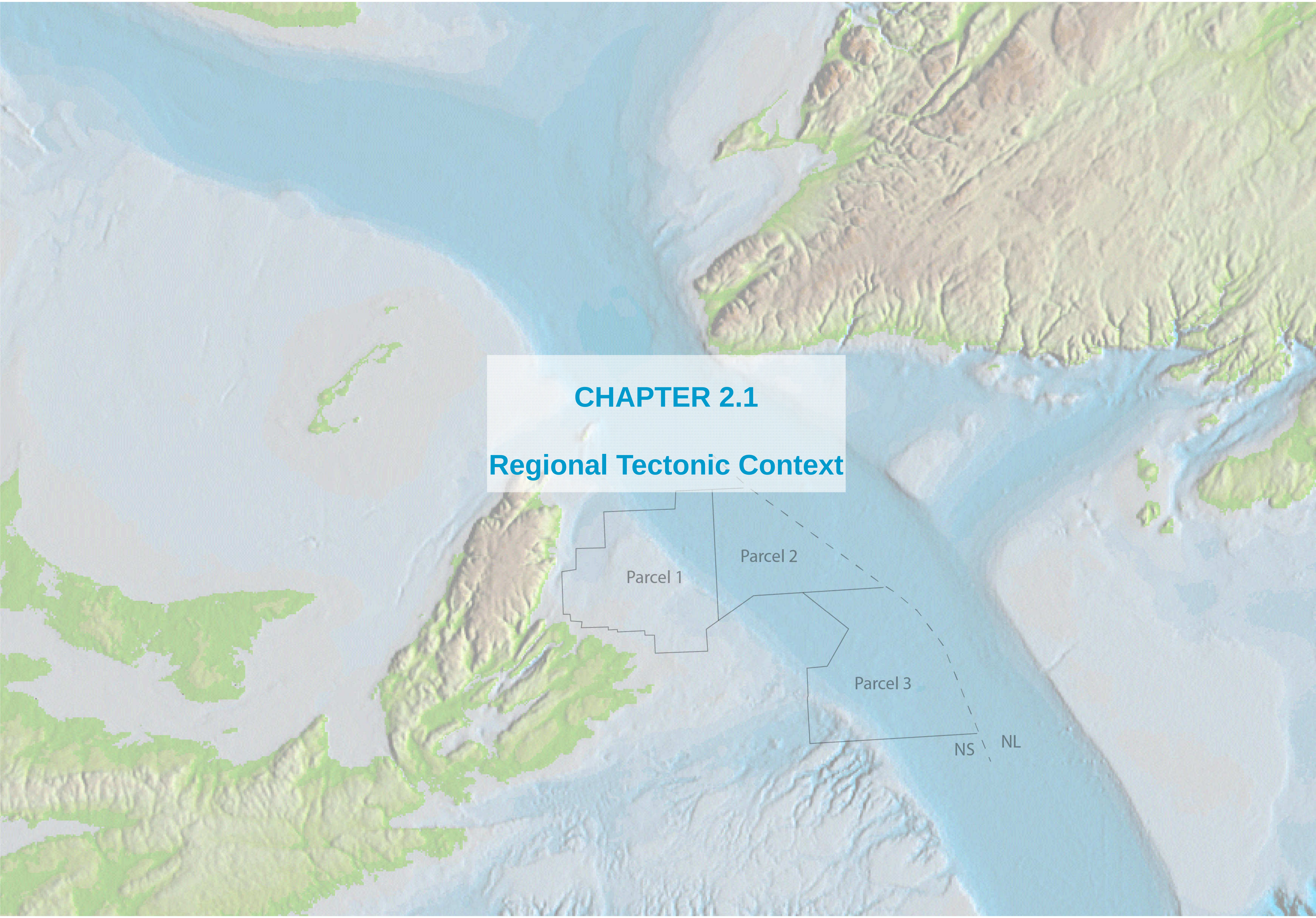
CHAPTER 2

TECTONIC SETTING AND STRUCTURAL STYLE



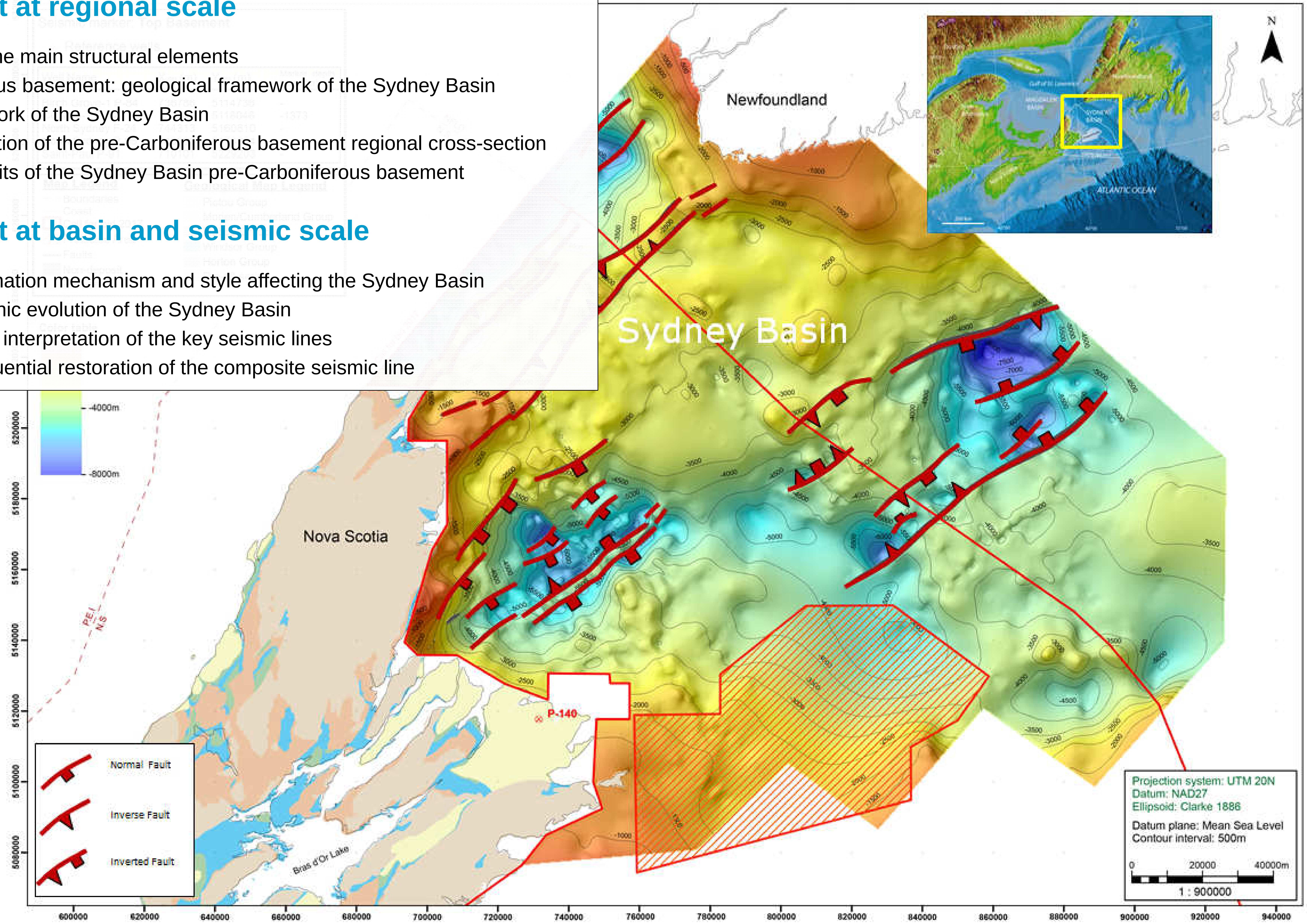
CHAPTER 2.1

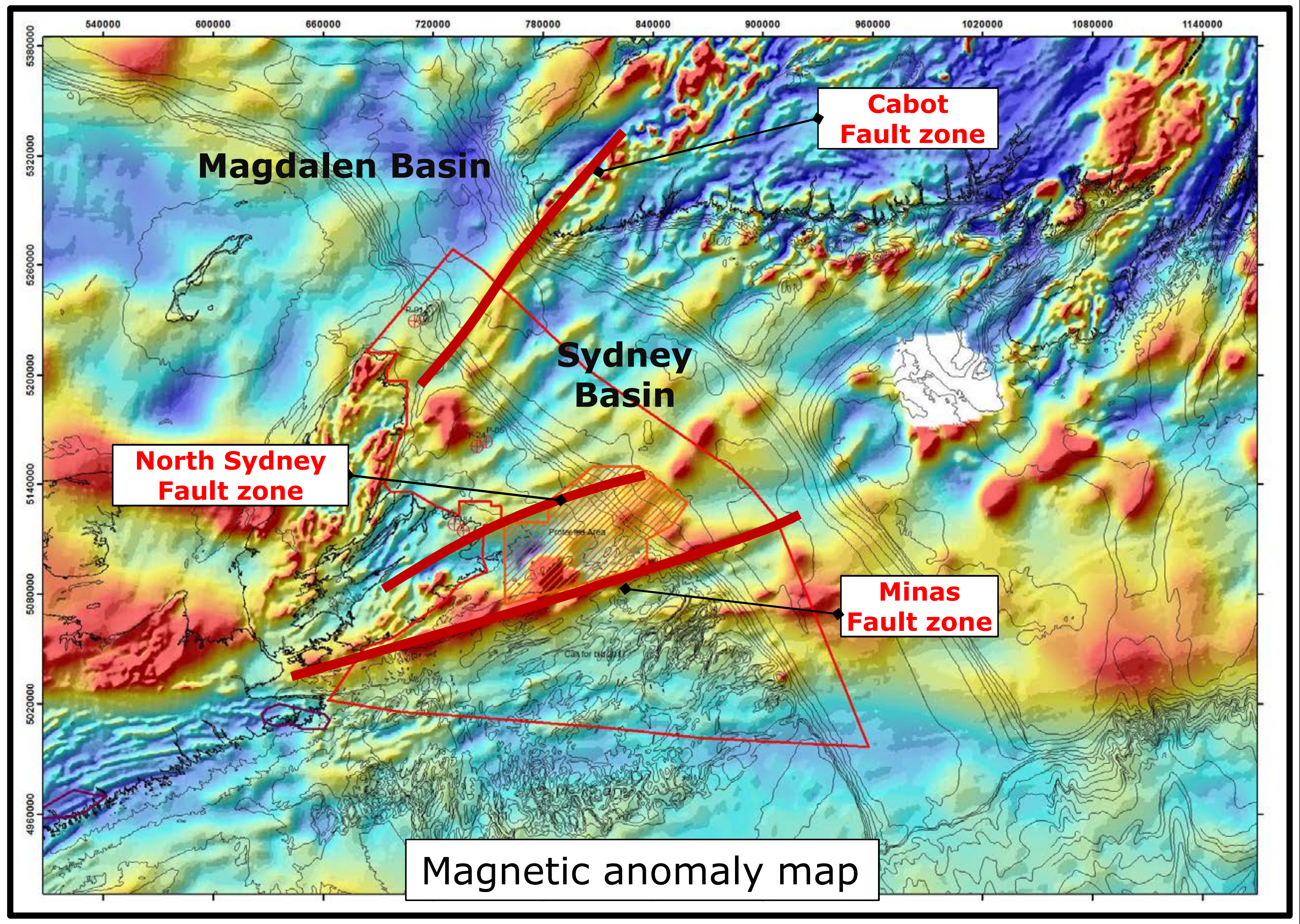
Regional Tectonic Context

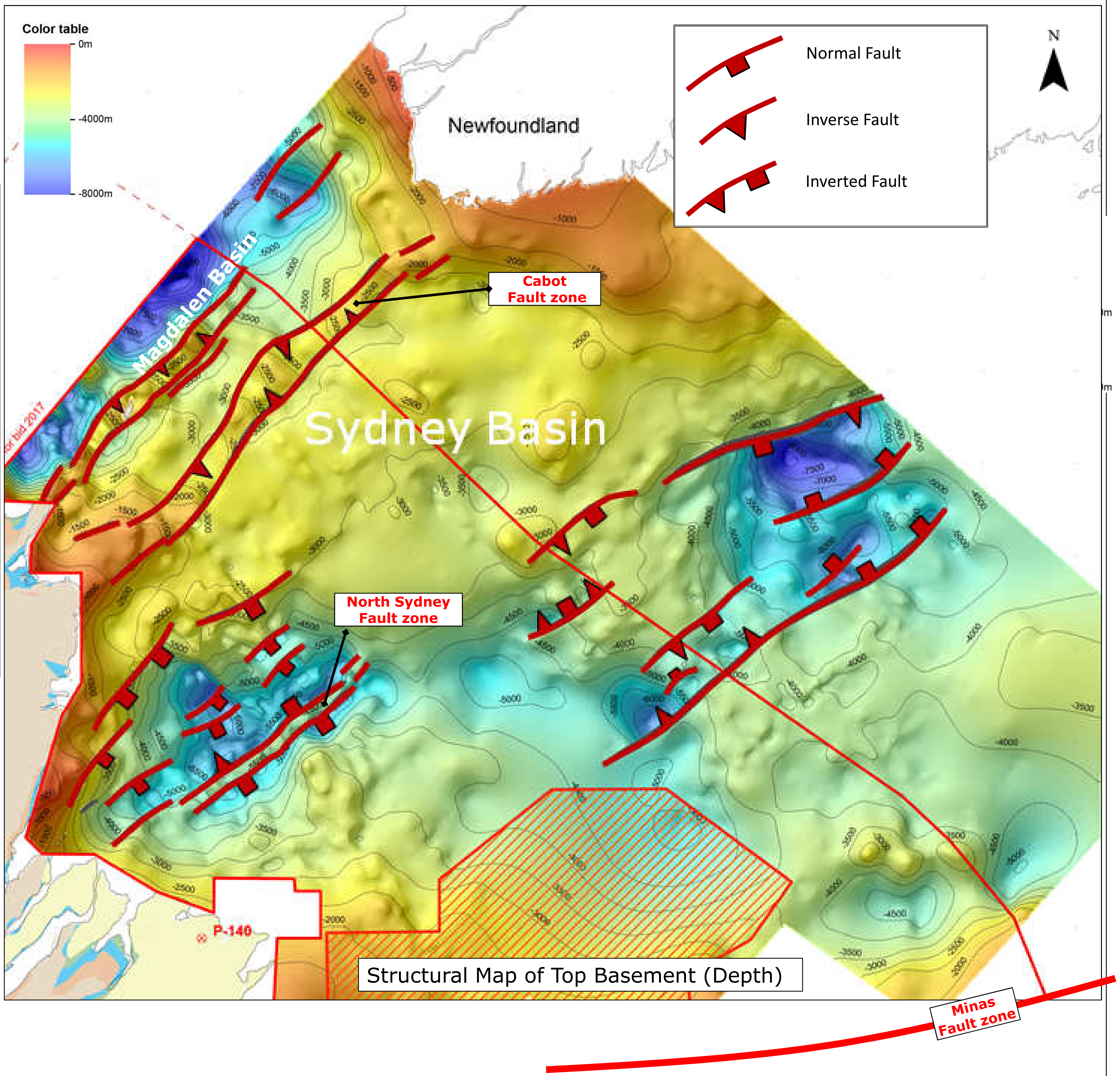


2.1 Tectonic context at regional scale

2.2 Tectonic context at basin and seismic scale







Pl. 2.1.2 **Sydney Basin: the main structural elements**

REGIONAL TECTONIC CONTEXT

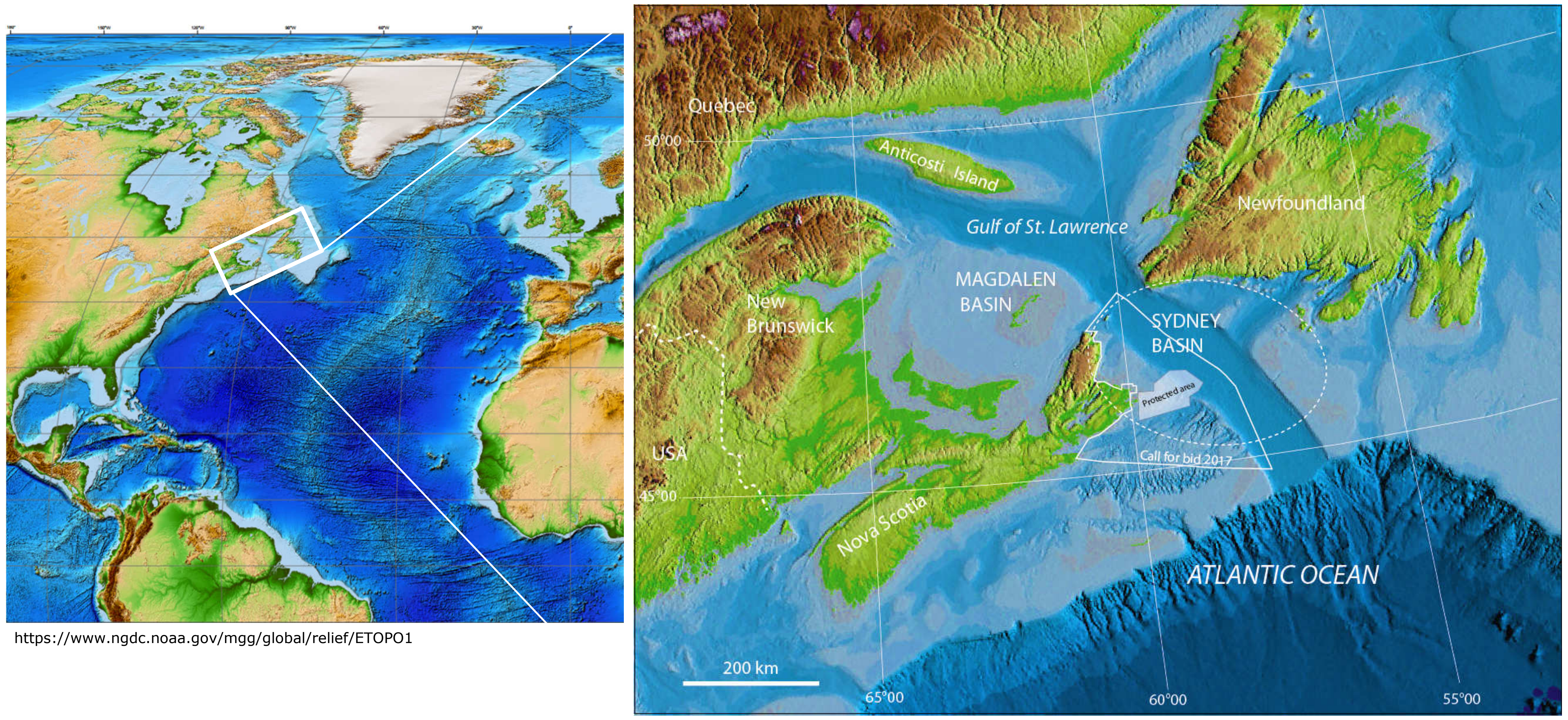


Figure 1 : Topographic and bathymetric map of eastern Canada (base map is taken from the DEM of Natural Resources Canada). The 2017 call for bids area is shown by the white polygon. The white shaded polygon is a marine protected area. The offshore Sydney Basin is located in the Cabot Strait between Cape Breton Island (Nova Scotia) and Newfoundland. The St. Lawrence submarine channel crosses through the entire offshore Sydney Basin. The offshore basin has an overall elliptical geometry and covers an area of approximately 250 000 km².

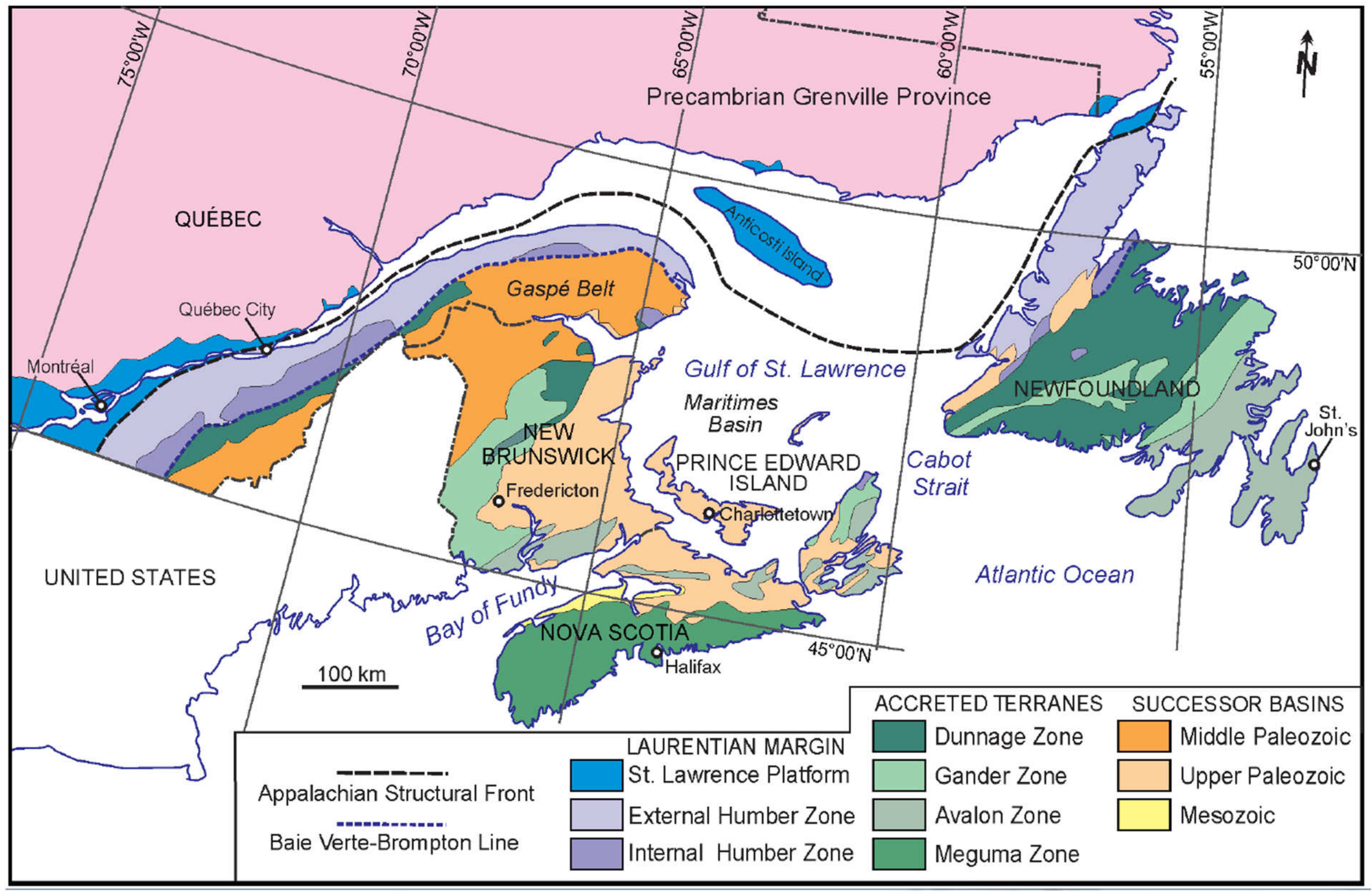


Figure 2: Regional tectonostratigraphic domains in eastern Canada (from Dietrich et al. 2011). The Sydney Basin is part of the largest Upper Palaeozoic Maritimes basins. Apart from the Laurentian platform, the pre-Carboniferous units (Humber zone and accreted terranes) constitute the metamorphic and magmatic basement of the Maritimes Basin.

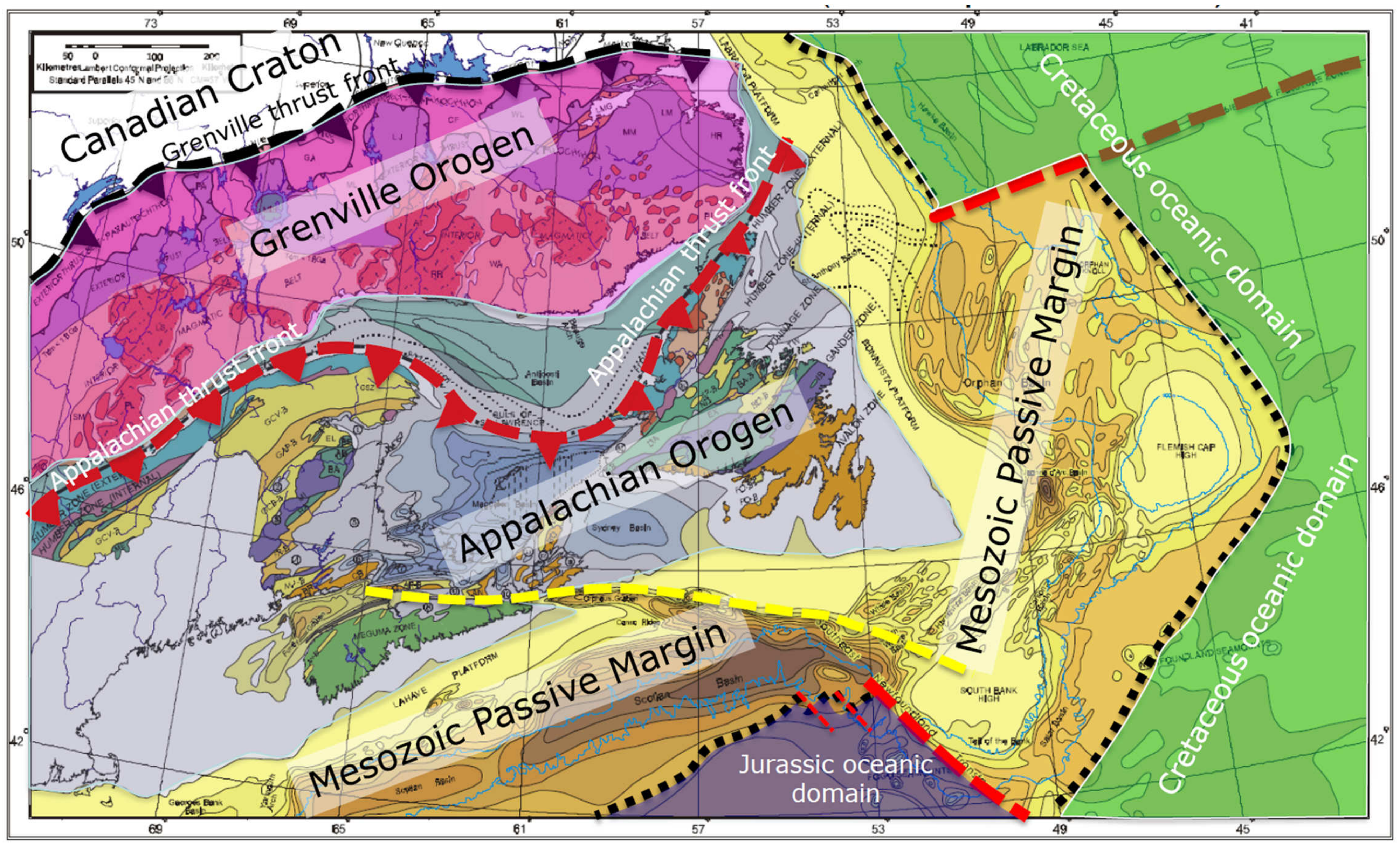


Figure 3 : Nova Scotia-Newfoundland main tectonic units. 1) Canadian Archean and Proterozoic Craton (white) 2) Proterozoic Grenville Orogen (pinkish) 3) Palaeozoic units including Appalachian foreland and Appalachian Orogen (greyish) 4) Mesozoic passive margin (yellow and brown contour map) 5) Jurassic oceanic domain (violet) 6) Cretaceous oceanic domain (green)

The Sydney Basin is one of the various Carboniferous basins constituting the complex patchwork of the Maritimes Basin (Figure 4). This patchwork of basins developed on top of the Appalachian orogen (Figure 3, 4 and 7) and is mainly controlled by extensional and strike-slip faults with a general NE-SW orientation.

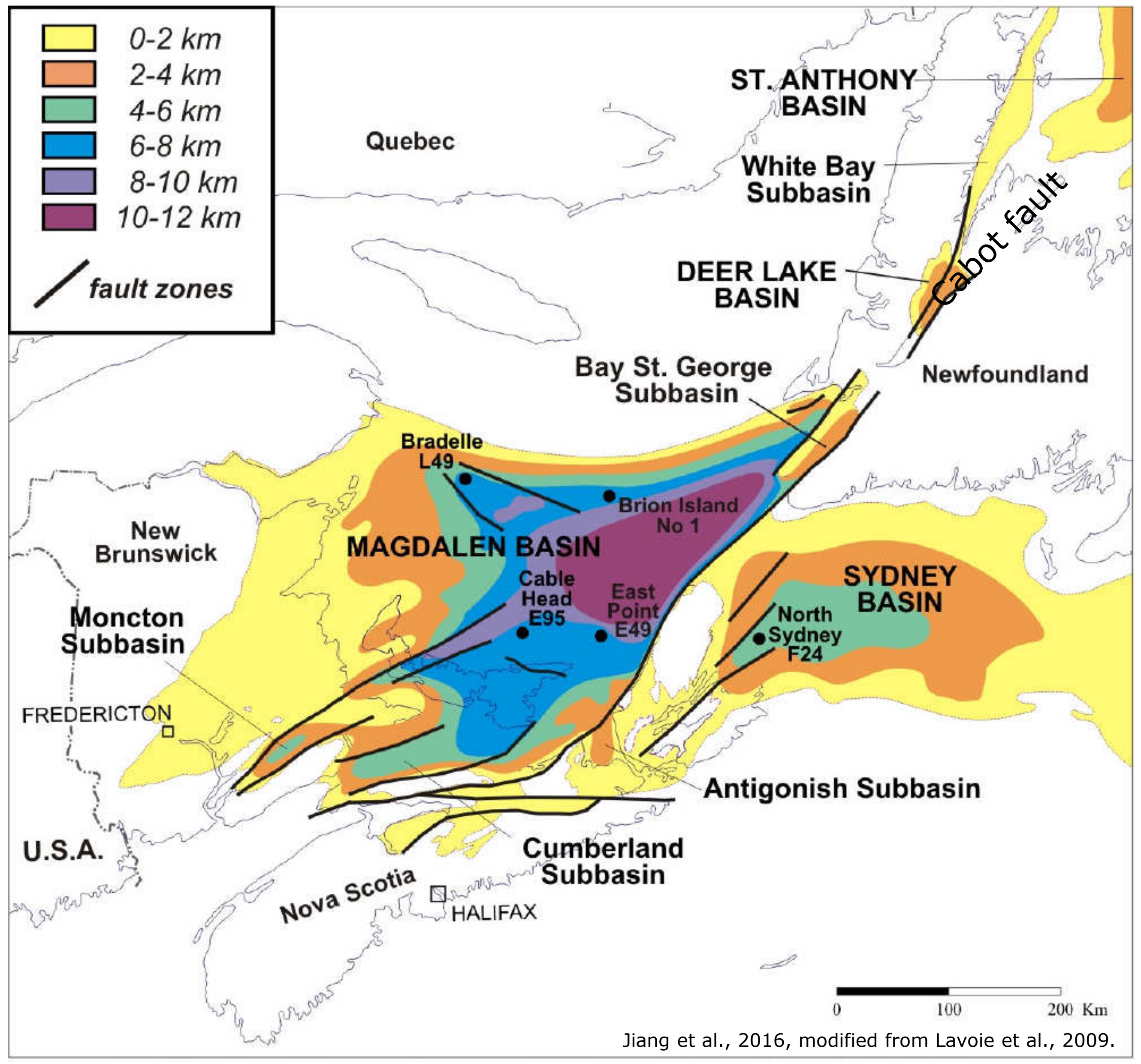


Figure 4: Isopach maps of the numerous sub-basins forming the Carboniferous Maritimes Basin (Jiang et al. 2016). The two largest and deepest sub-basins are the Magdalen Basin to the north and the Sydney Basin to the south. These two basins are separated by a major dextral strike-slip faults zone (the Cabot fault). Isopach contours in the Sydney Basin are approximate and have been revised in this study.

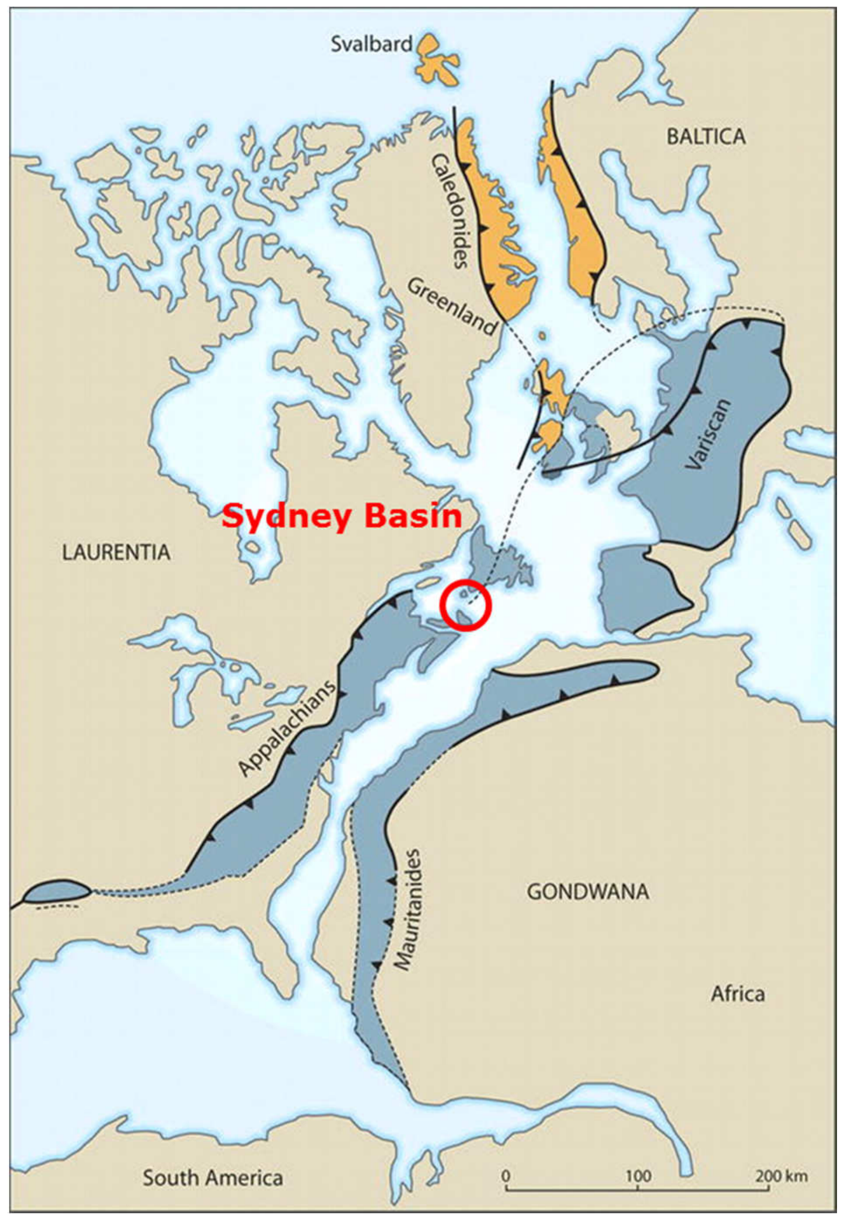


Figure 5: Caledonides and Variscan Appalachian mountain belts at the end of Carboniferous times (from Higgins, A. K., & Leslie, A. G., 2008). The Sydney Basin is superimposed on the Appalachian-Variscan belt.

Figure 7: Schematic regional cross-section linking the St. Lawrence foreland platform to the Nova Scotia passive margin. This section is a compilation of various published documents: Dietrich et al. 2011 for the St. Lawrence platform and Magdalen and Sydney basins; Keen and Williams 1990, for the Orpheus graben; PFA 2011 for the Nova Scotia margin. Moho was constrained from Petrescu et al. 2016 for the northern part of the section and by the OETR 2009 refraction results and Louden et al. 2010 reports for the southern part. Deep architecture below the Sydney Basin was simplified from Van der Velden et al. 2004. Due to zig-zag composite nature of this section, apparent relative size of the various basins must be considered with caution (i.e. width of the Magdalen Basin). Discontinuous segments of the section (see inset for location) are underlined by white shaded vertical strips.

This schematic section shows three main tectonic domains from north to south:

1)The St. Lawrence platform constituting the foreland autochthon domain of the Taconic-Appalachian belt. This platform consists of a metamorphic and magmatic basement emplaced during the Precambrian orogens: Superior (not shown in this section) and Grenville orogens. This basement is overlain by Early Paleozoic (Cambrian to Devonian) shallow marine to nearshore sediments.

2)The Magdalen and Sydney basins superimposed on the complex Taconic-Neoacadian belt composed principally of metamorphic and magmatic rocks. These two Carboniferous basins that developed by intracontinental extension and strike-slip faulting are filled by continental and shallow marine (evaporitic) deposits. The two basins are separated by the Cabot fault, a major right lateral crustal scale fault. These two "intracontinental basins were only deformed by the Alleghanian late Carboniferous Permian event (Figure 6)

3) The Nova Scotia Mesozoic passive margin developed during Mesozoic time. This domain is bounded by a major trans tensional left lateral fault (the Cobequid Chedabucto or Minas fault) controlling the pull-apart Orpheus half graben formation and is characterized by a thinned continental crust connected to the oceanic domain by a high velocity zone interpreted as underplated intrusive (OERA 2011) or serpentinized mantle (Beaumont, 2011 and Louden et al. 2010).

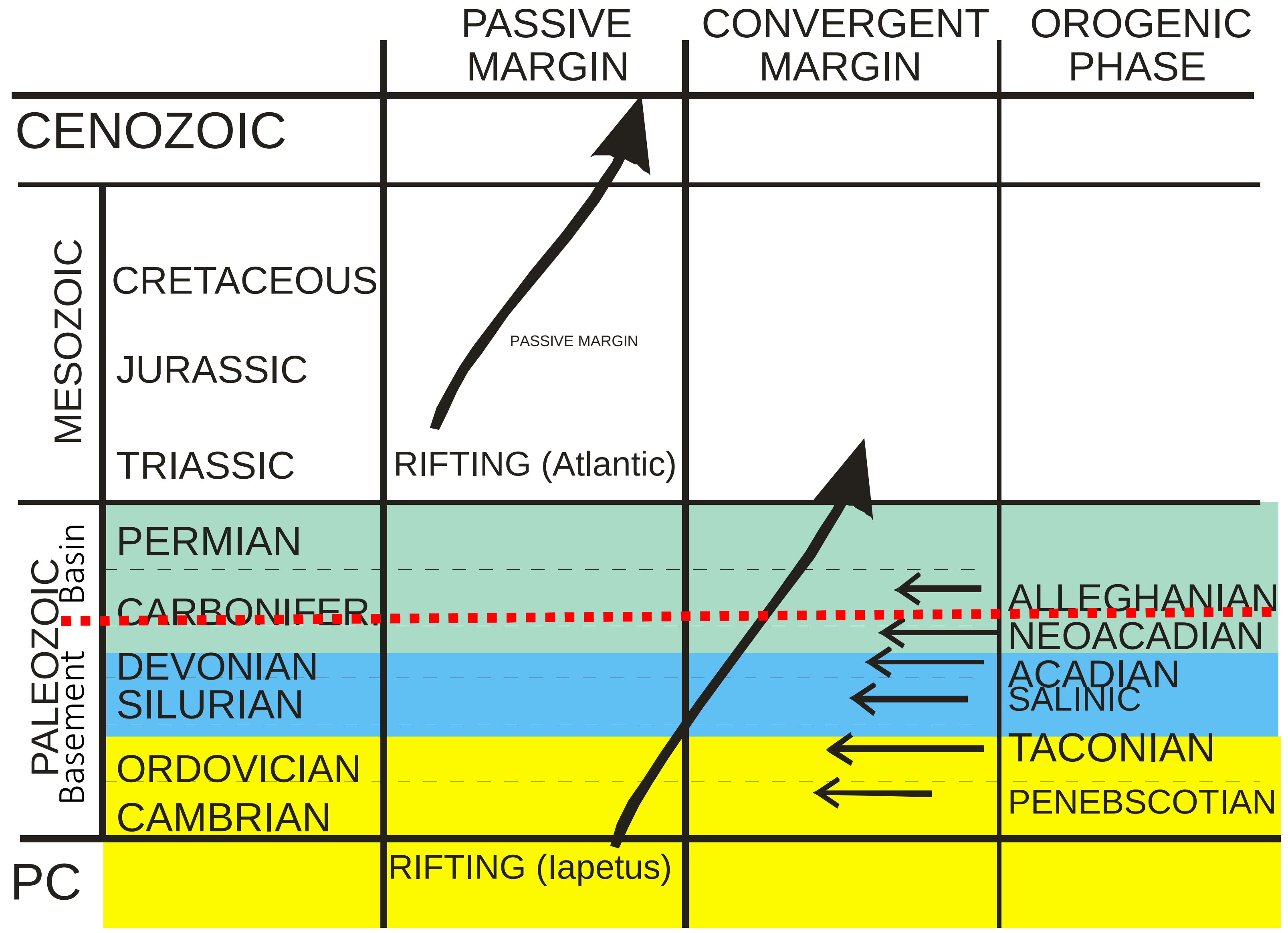
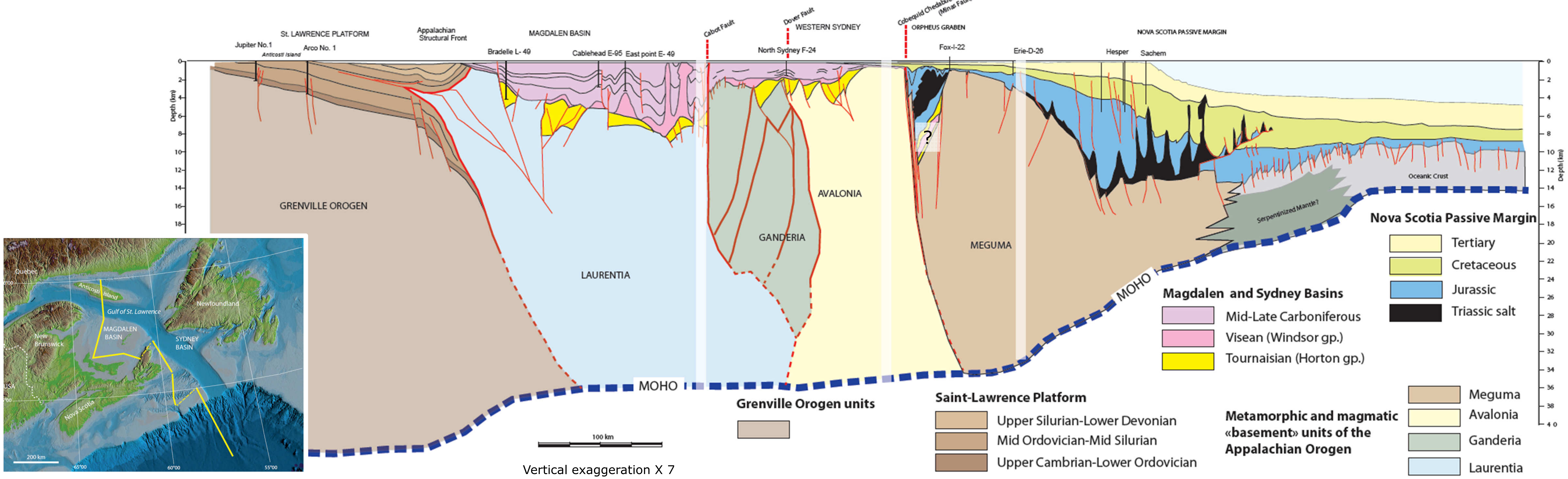
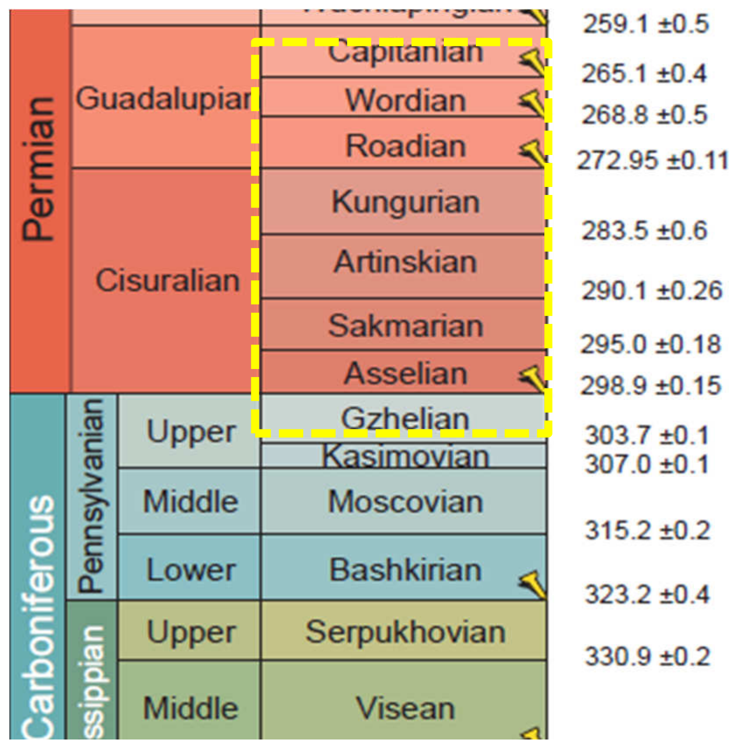


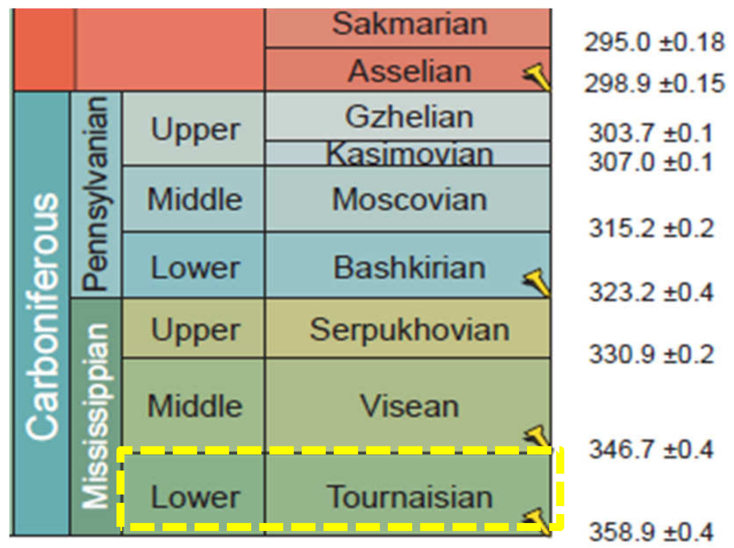
Figure 6: Main tectonic events of eastern Canada (from Lavoie et al. 2009). Basement of the Sydney Basin consists of metamorphic and plutonic units deformed and accreted to the Laurentian margin during the 4 major tectonic events (Taconian, Salinic, Acadian, Neoacadian). The Sydney sediments rest unconformably on top of the crystalline Pre-Carboniferous basement and were poorly deformed (inversion of normal faults, strike-slip faults) during the late Carboniferous-Permian Alleghanian compressional event.



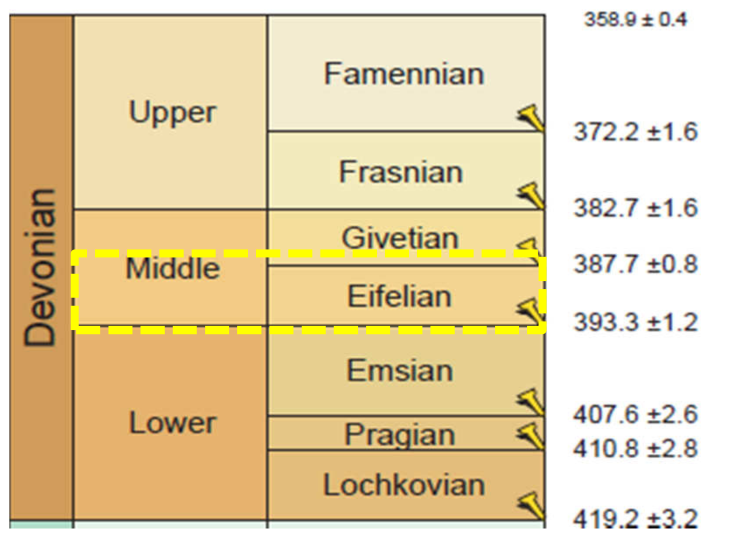
Tectonic framework of the Sydney Basin



EARLY CARBONIFEROUS



MID DEVONIAN



EARLY DEVONIAN

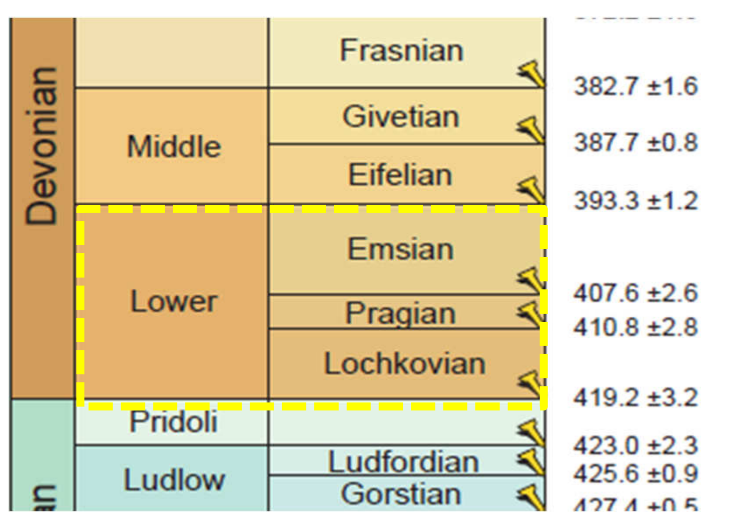
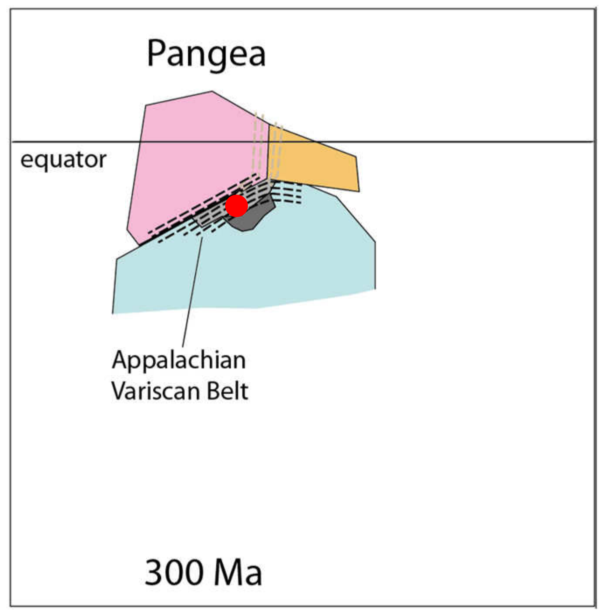
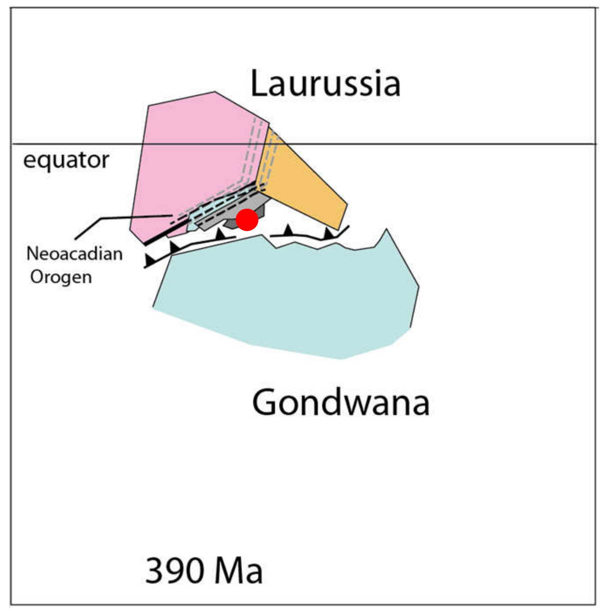


Figure 8: Schematic geodynamic evolution reconstruction modified from Termier and Termier, [*http://www.universalis.fr/encyclopedie/vari sques-chaines-hercyniennes*](http://www.universalis.fr/encyclopedie/varisques-chaines-hercyniennes) *Red dots indicate the paleo locations of the tectonic components of the Sydney Basin pre-Carboniferous basement.*



In the reconstruction shown in Figure 8, a non-oblique convergence is proposed, while in the palinspastic reconstructions of Figure 9, a clear dextral oblique convergence is supposed to occur in Devonian times along the paleo South American block, and during the Carboniferous, along the paleo African block (Matthews et al. 2016).



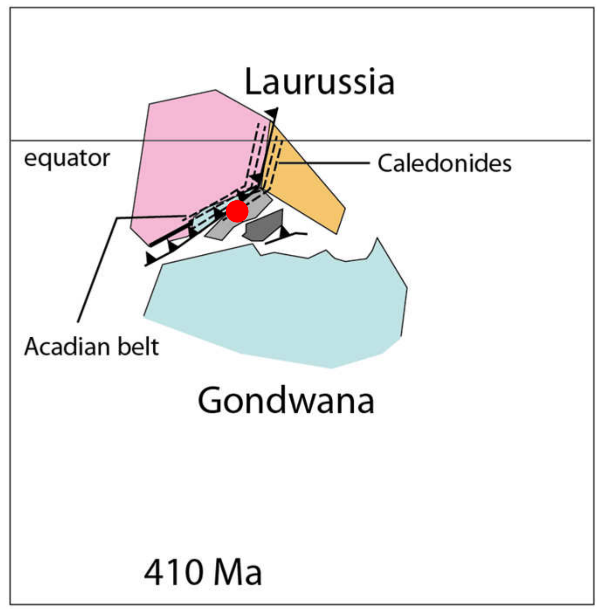
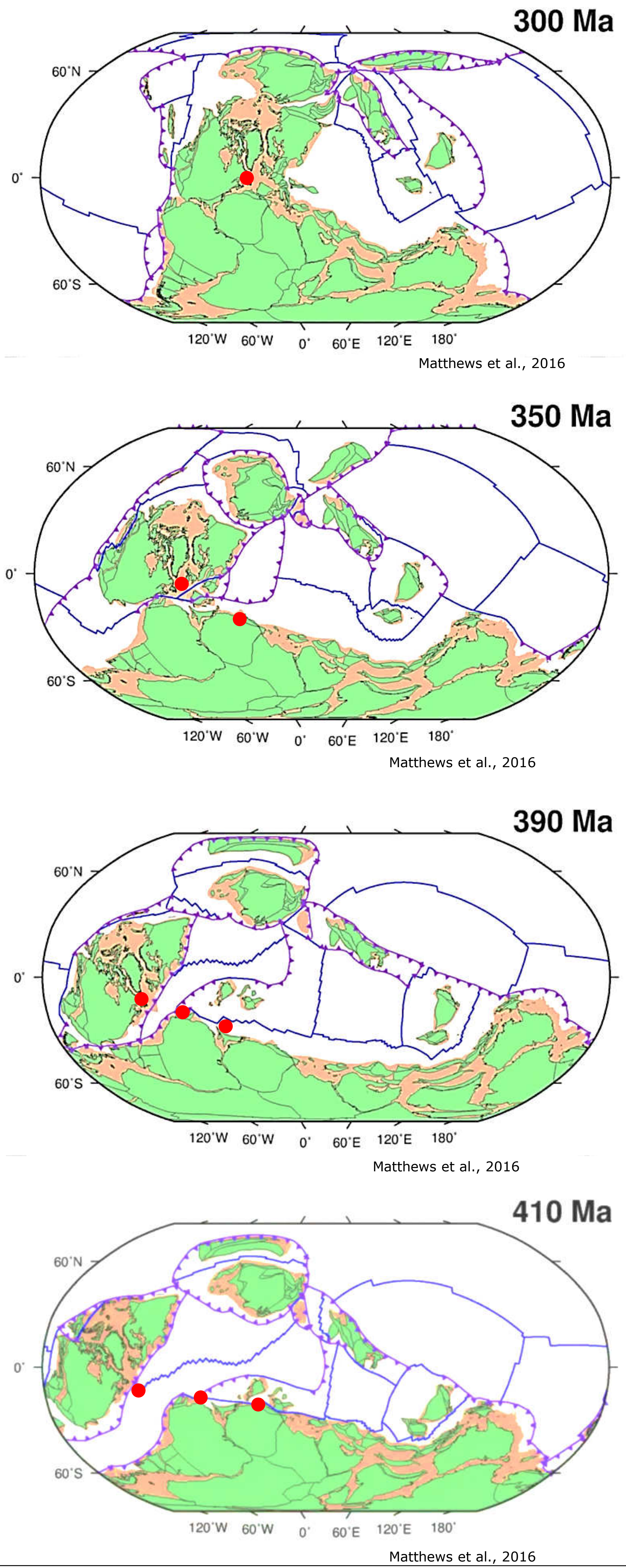


Figure 9: Plate reconstruction between 410 and 300 Ma showing that the terranes constituting the pre-Carboniferous basement of the Sydney Basin red dots) were separated by oceanic domains (Matthews et al. 2016). The accretion of these terranes resulted from the dextral oblique convergence of Gondwana and Laurentia.



ALLEGHANIAN OROGENY
It is the latest (300 to 250 Ma) and mildest tectonic event of the Appalachian orogeny. It corresponds to the final closure between Laurussia and Gondwana. At the end of this event, all the Oceanic domains and seaways have been closed and the 3 large continental blocks (Laurentia, Baltica and Godwana) have been aggregated creating the Pangea megacontinent. This event caused the deformation of the Sydney Basin inducing normal fault inversion and strike-slip faults (see plates 2-6, 7, 8, 9 and 10).

NEOACADIAN OROGENY
4th Appalachian phase:
During Late Devonian-Early Carboniferous times, the oblique (with probable large dextral strike-slip component) collision of the Meguma exotic bock caused the last major tectonic event of the Appalachian. This event was related to granitoid magmatism.

ACADIAN OROGENY
3rd Appalachian phase: The Acadian orogeny started during the Late Silurian at 421 Ma resulting from the oblique subduction and closure of the narrow Acadian seaway. Syn-collision Early Devonian magmatism indicates flat-slab subduction (van Staal and Barr 2012). This event is coeval to the Caledonian orogeny resulting from the collision of the Laurentia and Baltica continental blocks creating the Laurussia continent.

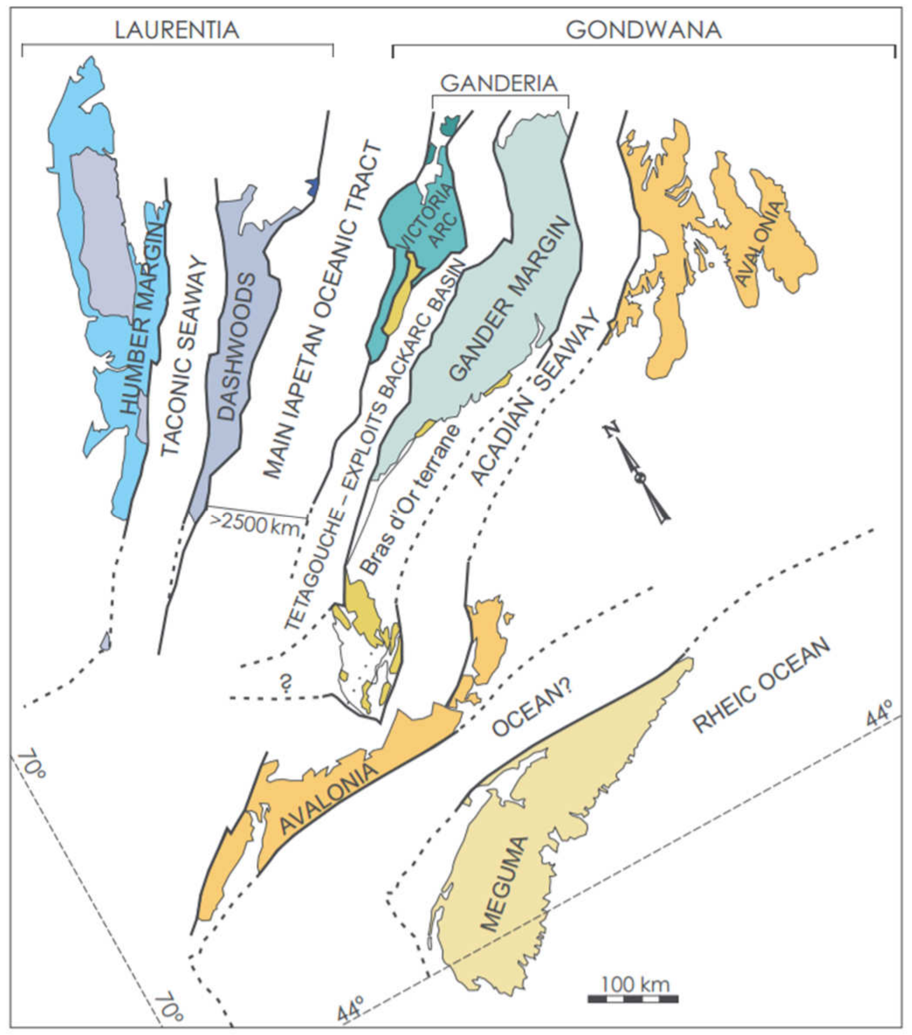
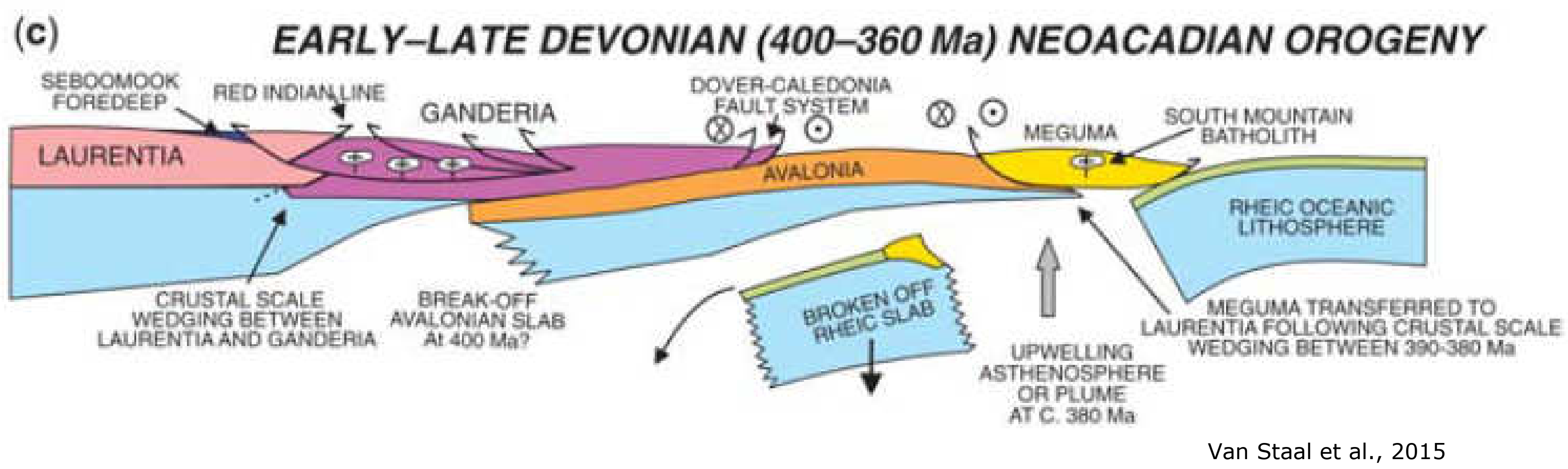
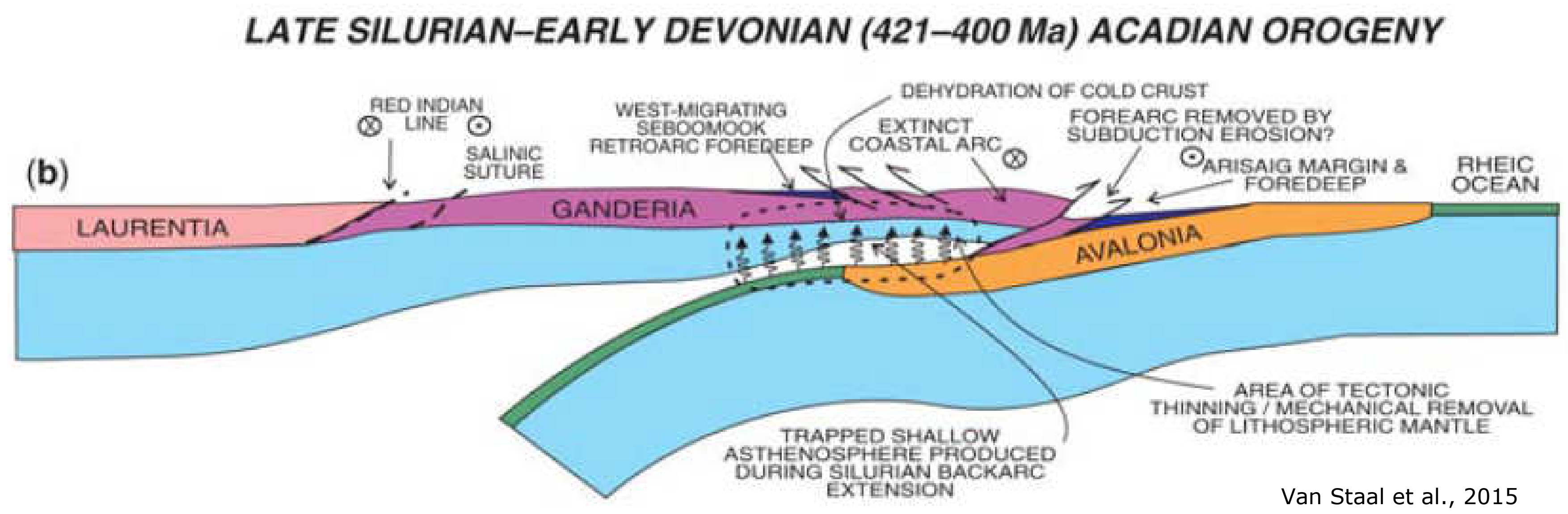
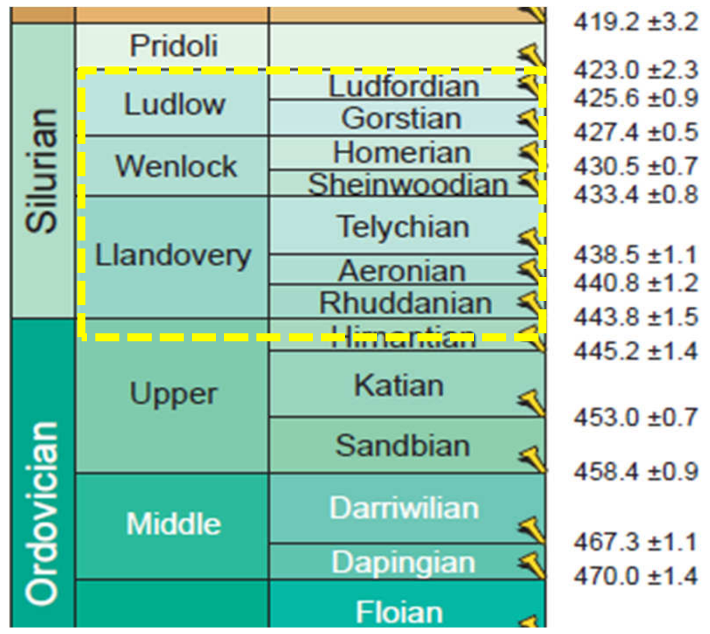


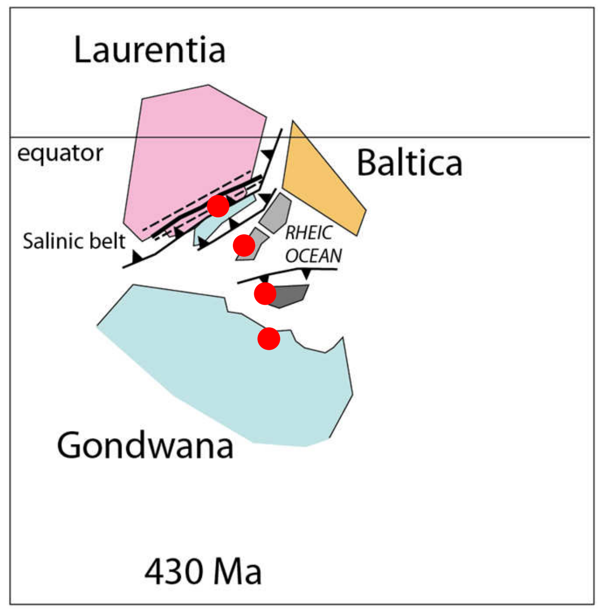
Figure 10: Lithotectonic elements of the Canadian Appalachians schematically expanded to show ocean and seaways that were present outboard (eastward) of the Laurentian margin (van Staal and Barr, 2012). Approximate location on Figure 12.



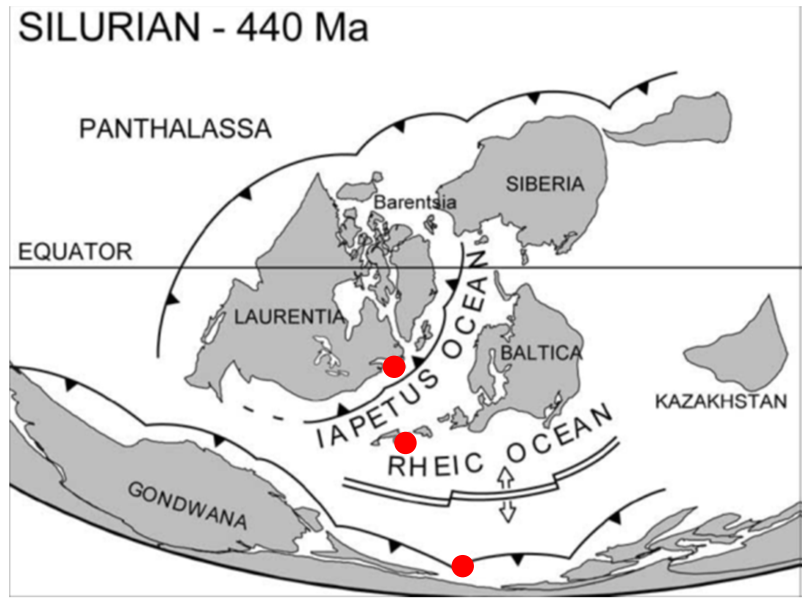


LATE ORDOVICIAN - EARLY SILURIAN

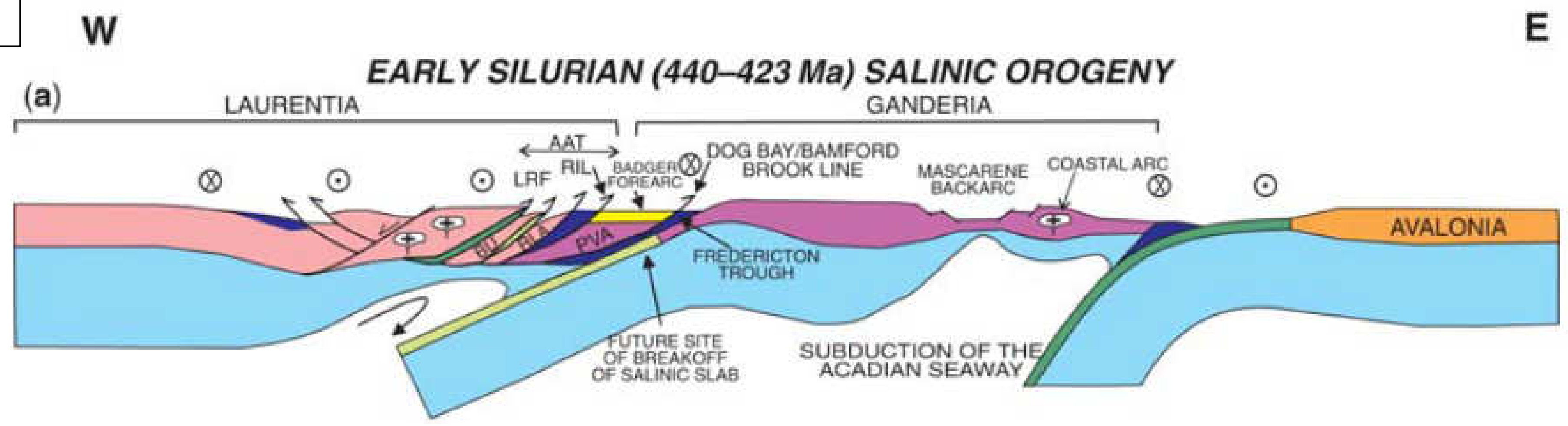




SALINIC OROGENY
2nd Appalachian phase: During Silurian times, accretion of the margin of the Ganderia block induced SE verging fold and thrust structures and syntectonic magmatism (433-423 Ma) related to a NW dipping subduction.

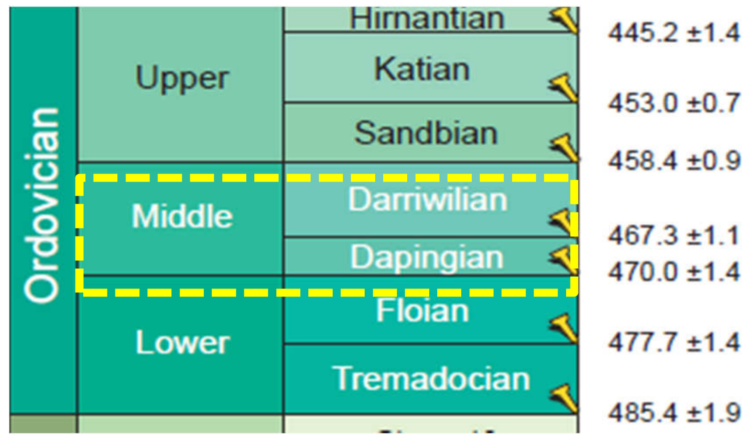


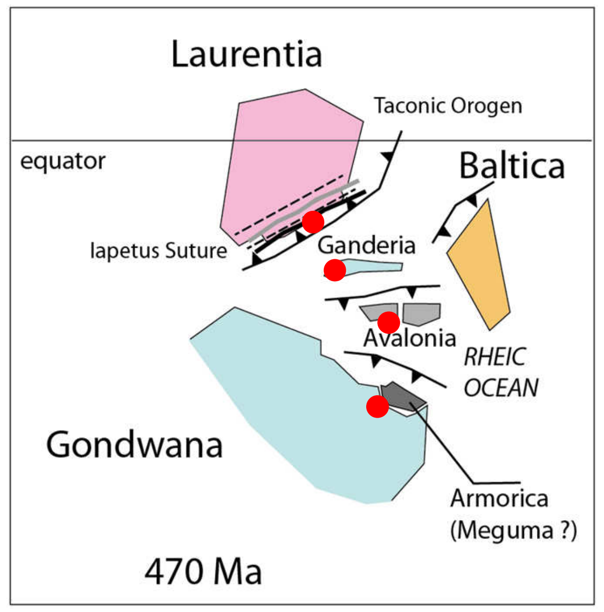
2001- C. R. Scotese Paleomap project



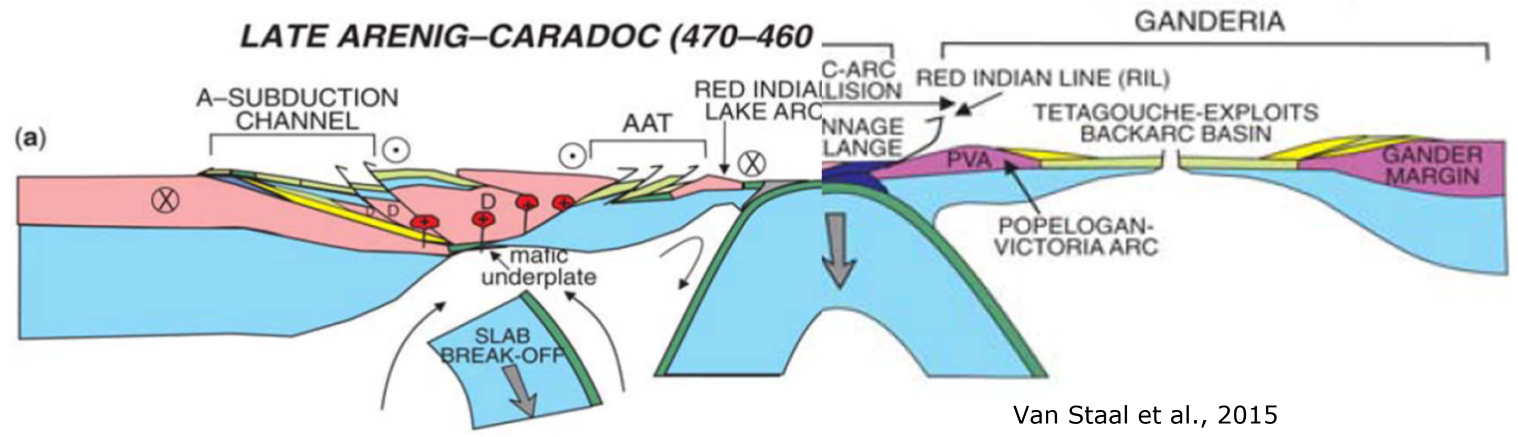
Van Staal et al., 2015

MID ORDOVICIAN



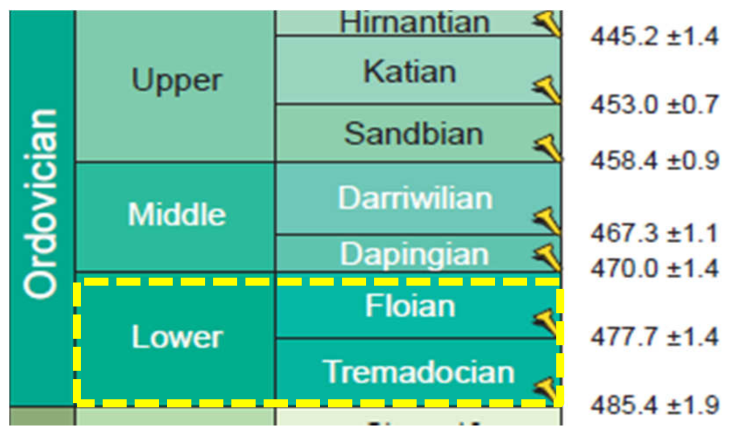


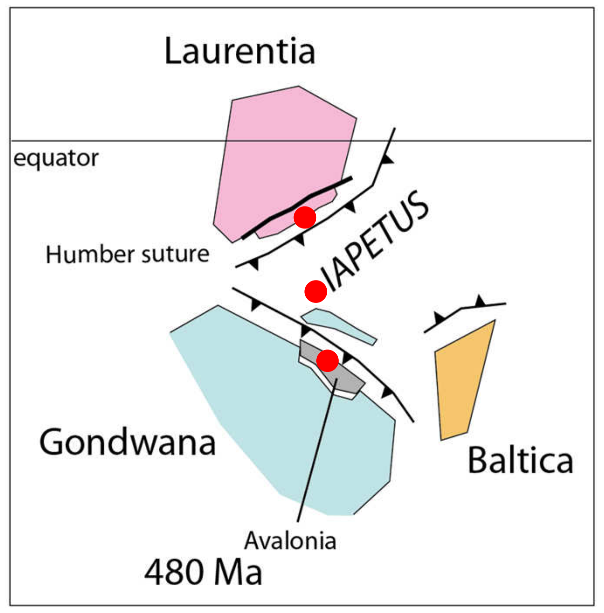
TACONIC OROGENY
1st Appalachian phase: During Ordovician times, continental microcontinents and volcanic arcs are accreted to the Laurentian blocks creating the Taconic belt (first orogenic phase of the Appalachian orogen). This orogeny is also responsible for important magmatic activity with numerous intrusive bodies.
Meanwhile 3 microcontinental blocks (Ganderia, Avalonia and Armorica) detached from Gondwana and migrated toward Laurentia inducing the opening of new oceanic domains (i.e. Rheic Ocean between Avalonia and Gondwana).

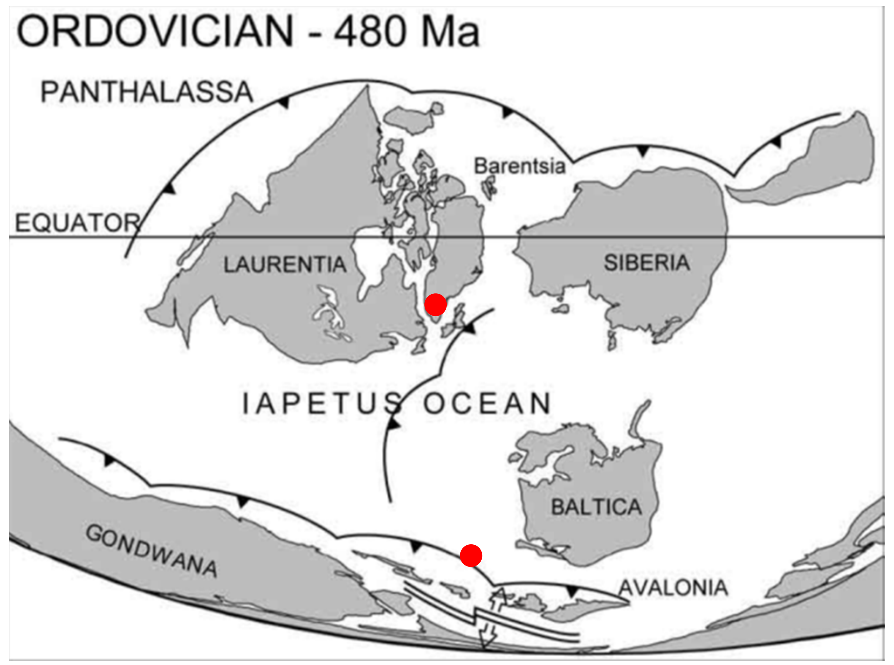


Van Staal et al., 2015

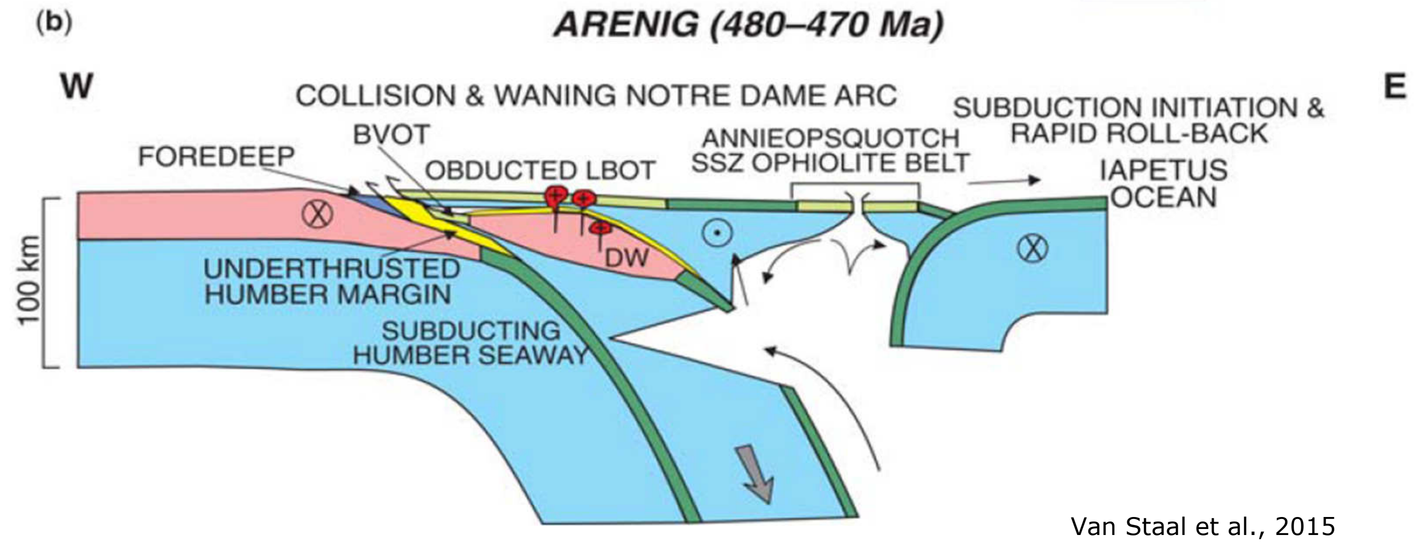
EARLY ORDOVICIAN





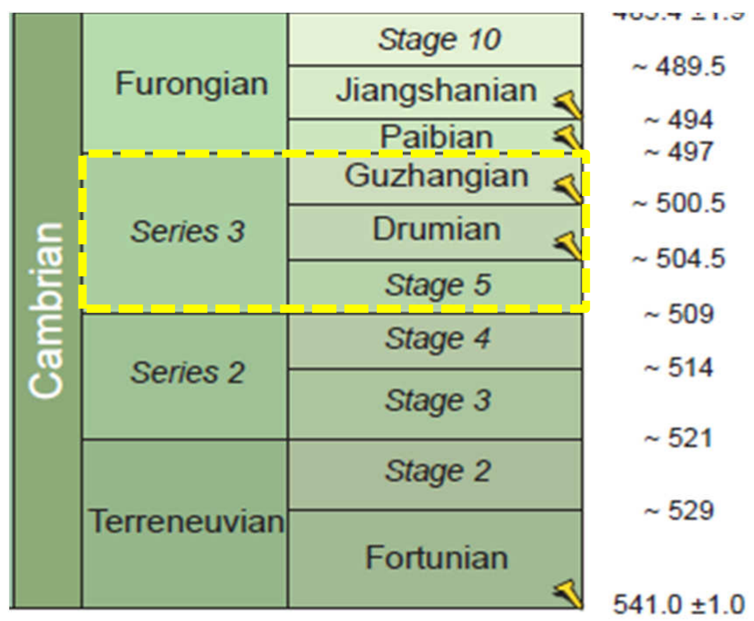


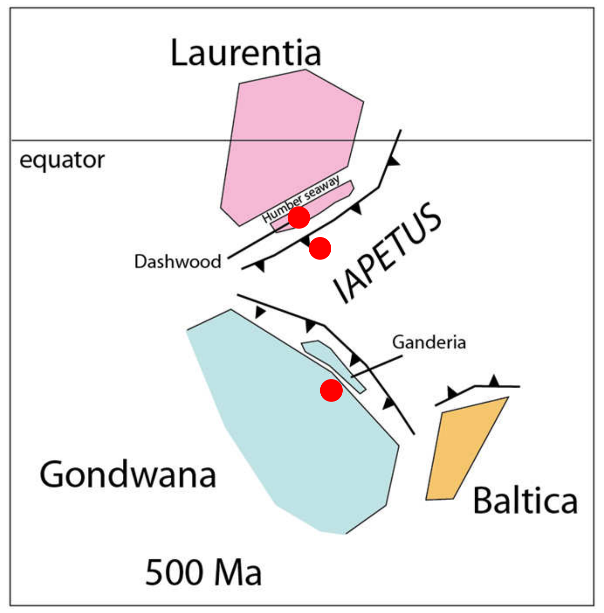
2001- C. R. Scotese Paleomap project



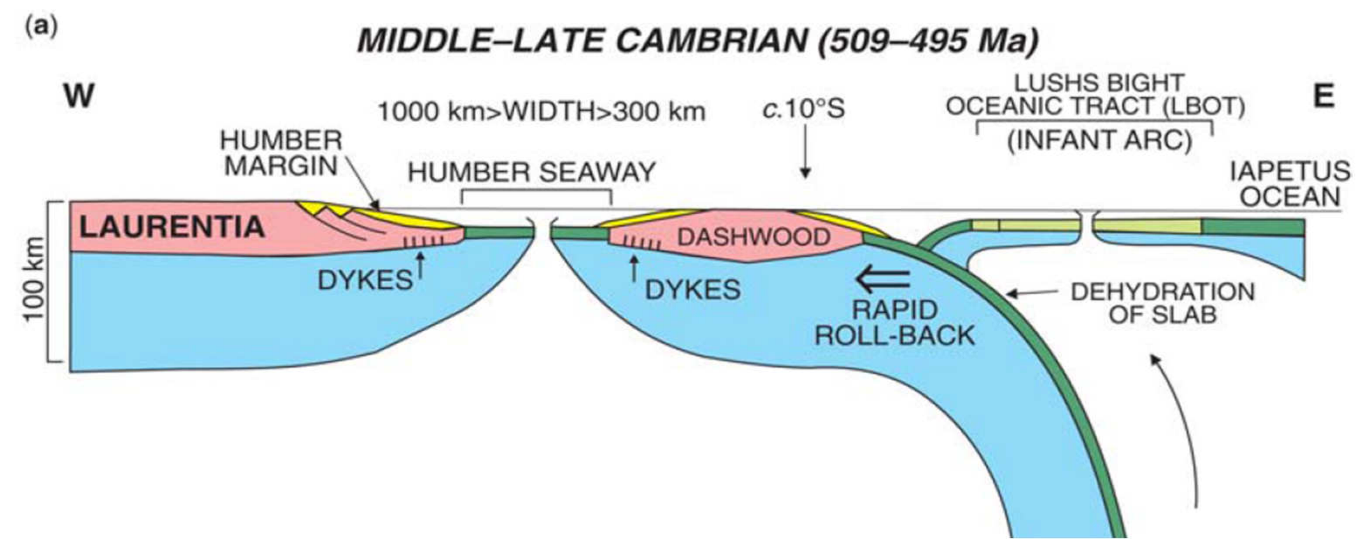
Van Staal et al., 2015

CAMBRIAN





In Cambrian times, the components of the future Sydney Basin basement are diverse (continental passive margin, volcanic arcs, and oceanic domains). These elements originated from 3 main tectonic domains: the Laurentian continental block, the Iapetus Ocean and the Gondwana continental block. They are separated by several thousands of km. From the end of Cambrian to the end of Carboniferous times, Gondwana and Laurentia converge (with some obliquity) inducing the closure of the Iapetus Ocean and the formation of the Appalachian metamorphic and magmatic belt.



Van Staal et al., 2015

Tectonic evolution of the Pre-Carboniferous basement (2)

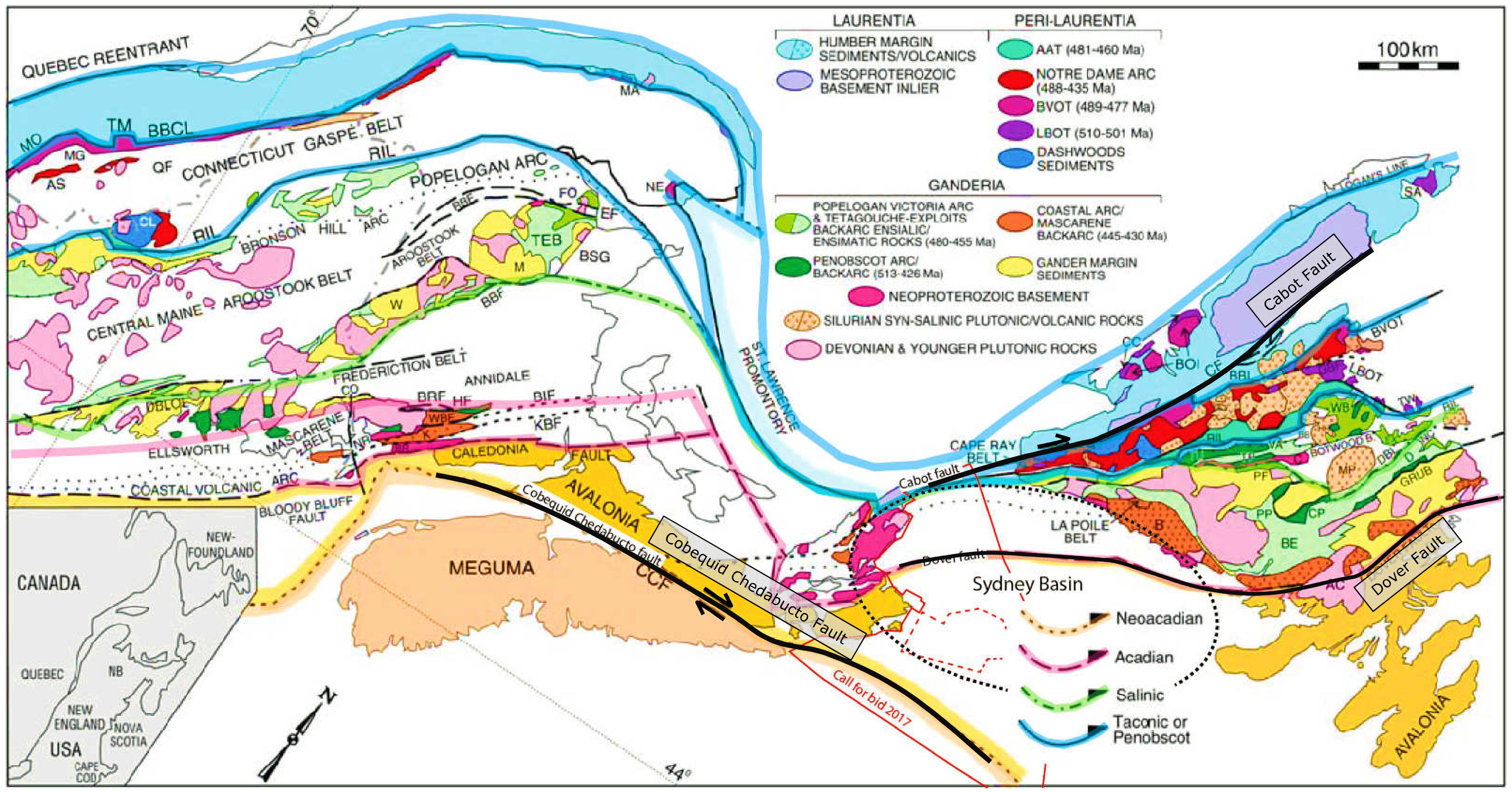


Figure 11: Major tectonic elements of the Canadian and US Appalachians defined by van Staal et al. 2009.
A, Arisaig Group; AC, Ackley granite; B, Burgeo batholith; BB, Badger Basin; BBF, Bamford Brook fault; BBL, Baie Verte Brompton Line; BVOT, Baie Verte oceanic tract; CCF, Cobequid–Chedabucto fault; CF, Cabot fault; CL, Chain Lakes Massif; CO, Cookson Group; DBL, Dog Bay Line; FO, Fournier Group; F, Fogo Island pluton; GBF, Green Bay fault;
GRUB, Gander River ultrabasic belt; HH, Hodges Hill pluton; LBOT, Lushs Bight oceanic tract; MP, Mount Peyton pluton; RBF, Rocky Brook–Millstream fault system;
RF, Restigouche fault; RIL, Red Indian Line; SGB, St. George batholith; SM, South Mountain batholith; U, Utopia granite; VA, Victoria arc; TP, Tally Pond Group.

In the Sydney Basin area, pre-Carboniferous basement corresponds to only two orogenic units: the Salinic and the Acadian orogens. These units are bordered by 3 major faults:

1) the Cabot fault separating the Salinic orogen (corresponding to the Ganderia paleoblock) from the Taconic orogen (corresponding to the Laurentian and Peri-Laurentian paleoblocks). The Taconic orogen constitutes the pre-Carboniferous basement of the Magdalen Basin to the north. Note that this fault or fault zone is the main oceanic suture corresponding to the closure of the Iapetus paleo-Ocean.

2) The Dover fault separating the Salinic orogen from the Acadian orogen resulting from the accretion of the Avalonia margin and paleo-continent to the Salinic and Taconic belt. It can be considered as a suture zone corresponding to the closure of the Acadian seaway (Figure 11).

3) The Cobequid Chedabucto fault separates the Acadian orogen from the Neoacadian orogen. It separates the Meguma paleo continental block from the Avalonia block. Note that this fault which had a probably dextral strike-slip component during Paleozoic times was reactivated as transtensional sinistral strike slip fault, creating the Orpheus pull-apart basin, during the Mesozoic opening of the Atlantic.

The pre-Carboniferous basement of the Sydney Basin is mainly composed of:

1) metasediments with various grade of metamorphism from very high grade (blueschist facies and, migmatite in the Salinic orogen), to locally poorly metamorphosed sediments in the Acadian orogen.

2) Intrusive plutons of various natures in all the tectonic units.

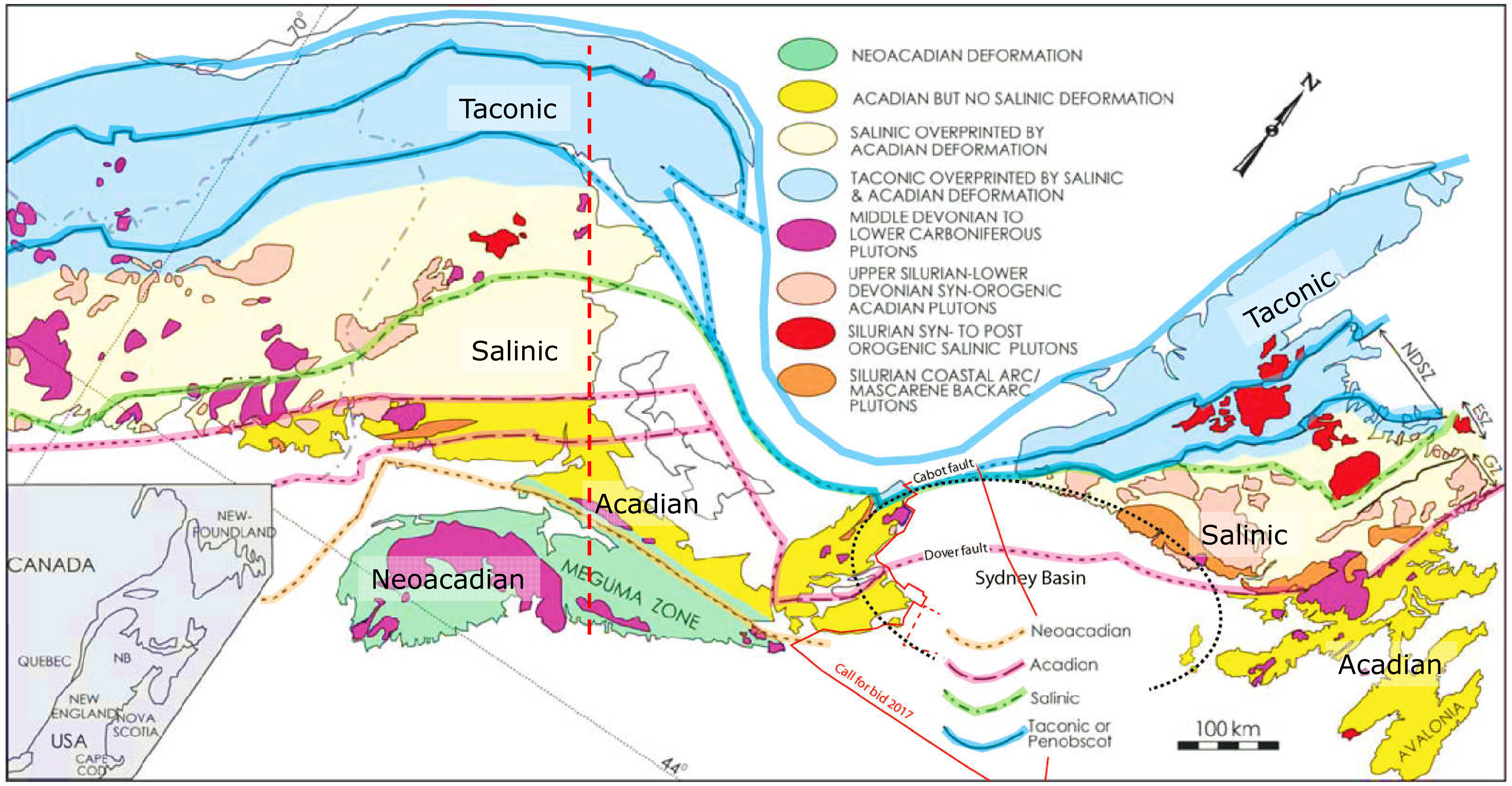
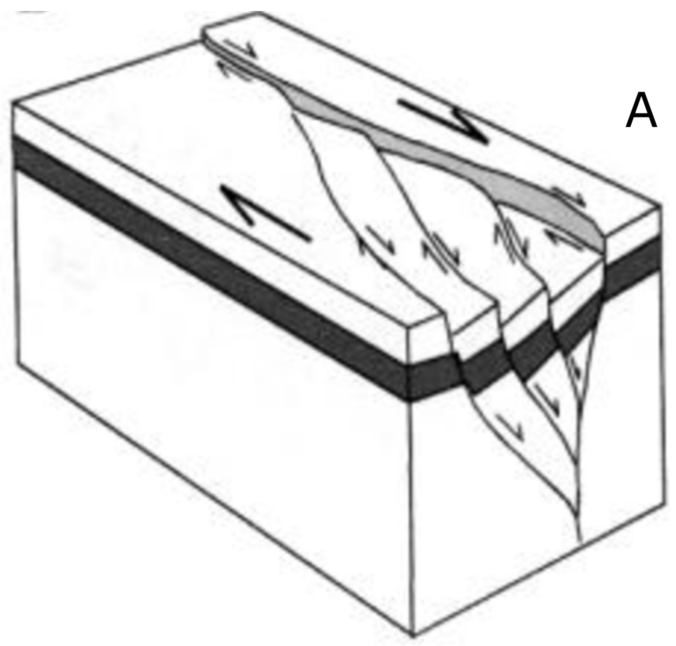


Figure 12: Orogenic belts and associated Silurian–Early Carboniferous plutonism of the Canadian and US Appalachians (modified from van Staal et al. 2009). Dashed red line shows the theoretical location of figure 10.

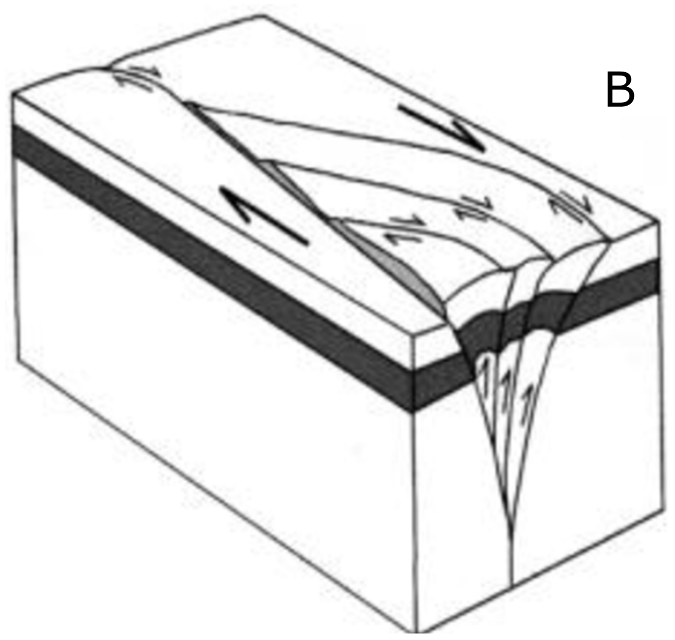
CHAPTER 2.2

STRUCTURAL STYLE AND STRUCTURAL RESTORATION

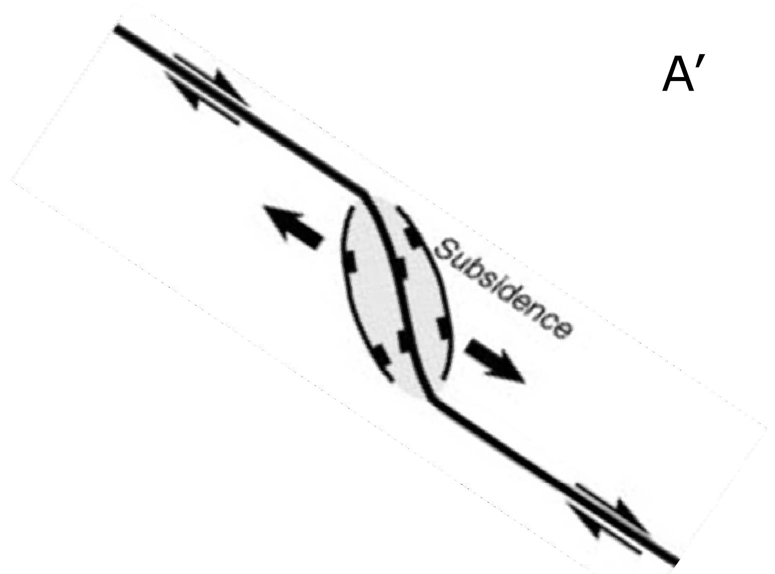
The main deformation mechanism and style of the Sydney Basin is represented by the inversion of a graben and semi-graben system under a transpressive regime.



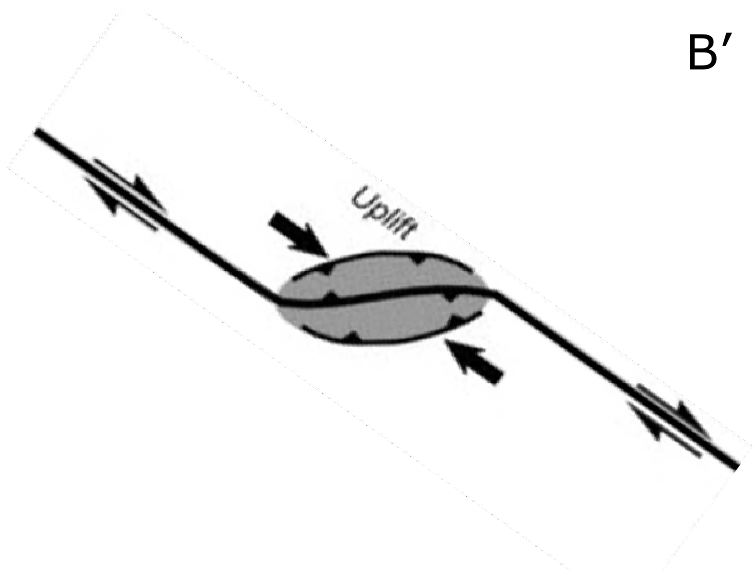
Schematic 3D illustration of a pull-apart basin formed under a (dextral) transtensive regime.



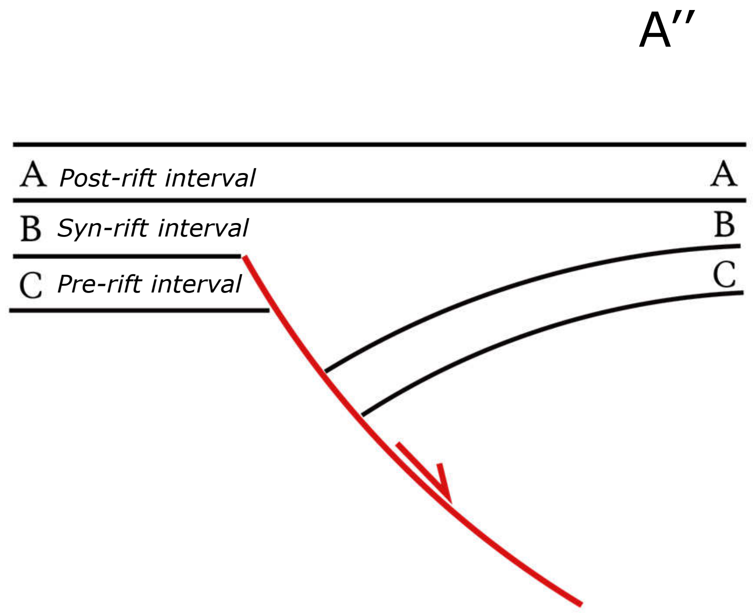
Schematic 3D illustration of a flower (pop-up) structure formed under a (dextral) tranpressive regime.



Schematic 2D illustration in map view of a pull-apart basin formed under a (dextral) transtensive regime.



Schematic 2D illustration in map view of a flower (pop-up) structure formed under a (dextral) transpressive regime.



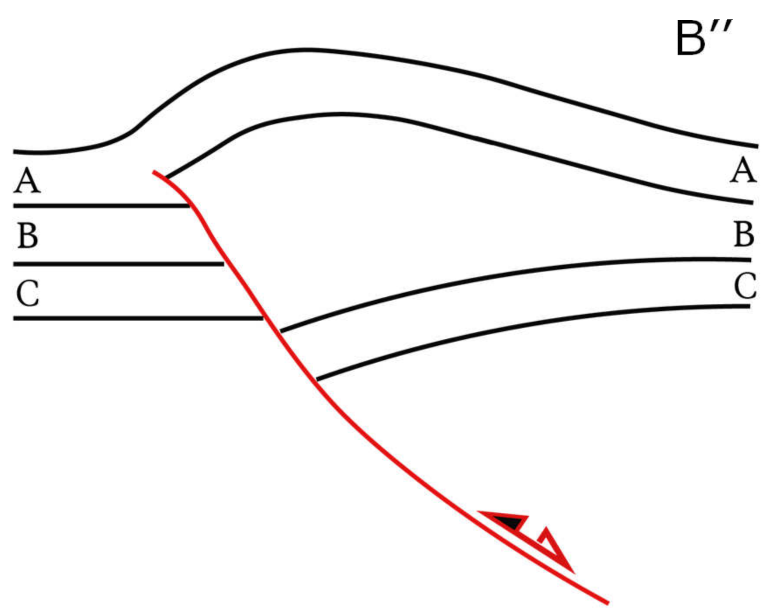


Figure 13: Schematic illustration of a tectonic inversion.
The figure on the left (A") shows the extensional phase and the figure on the right (B") the compressional one.

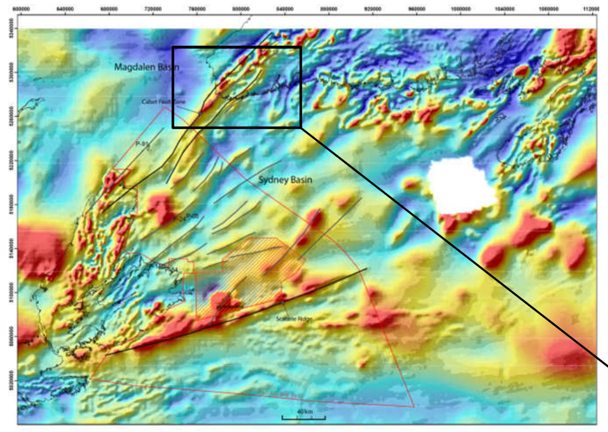
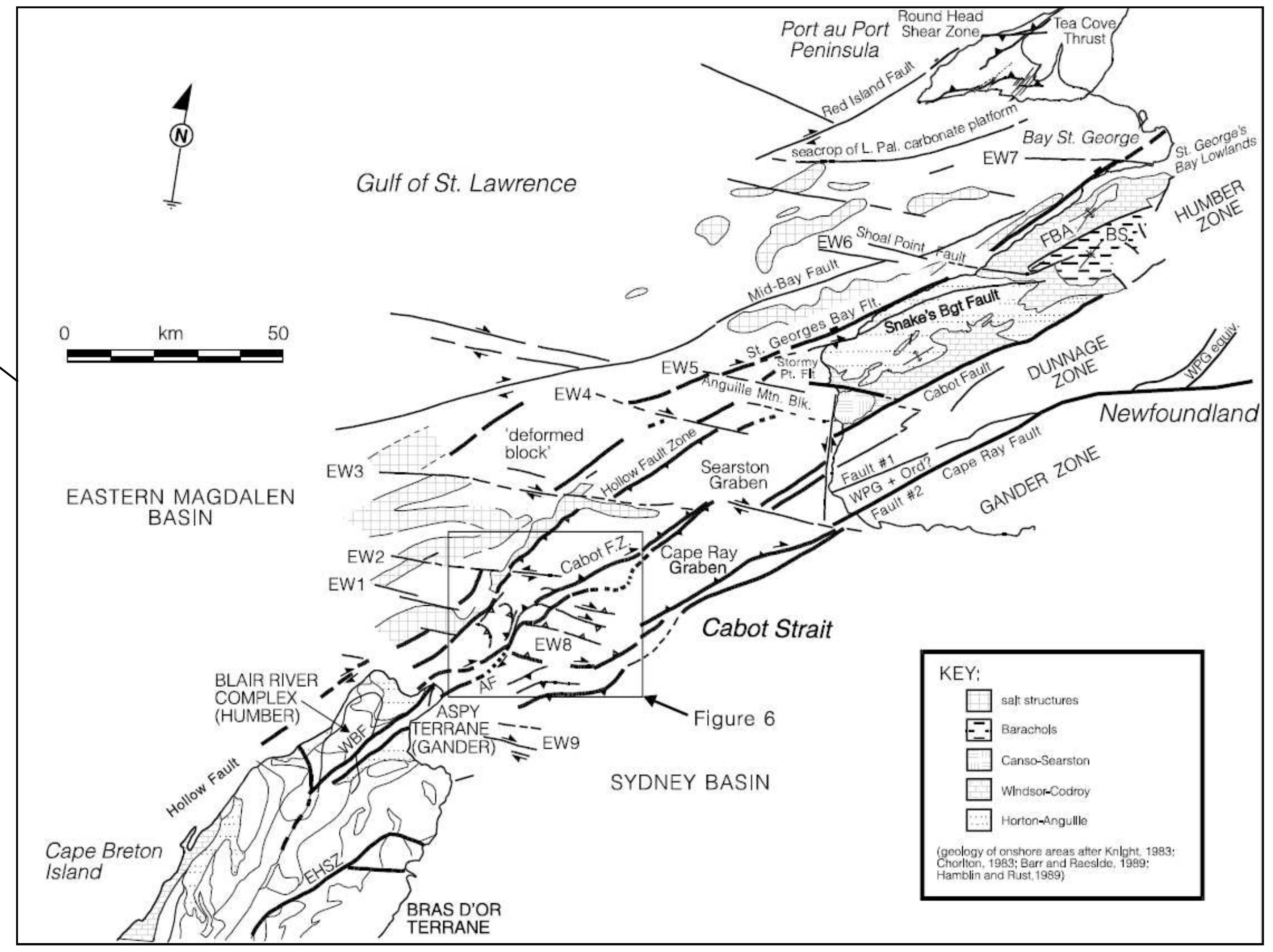


Figure 14: Structural map of the Cabot fault zone (Landon & Hall (1994).

The Cabot fault zone represents the north-westernmost boundary of the Sydney Basin. A structural analysis undertaken by Landon & Hall (1994) shows that the Cabot fault is a complex strike-slip system probably active under a transtensive regime during the early Carboniferous and under a transpressive regime during the late Palaeozoic (late Carboniferous/Permian?)



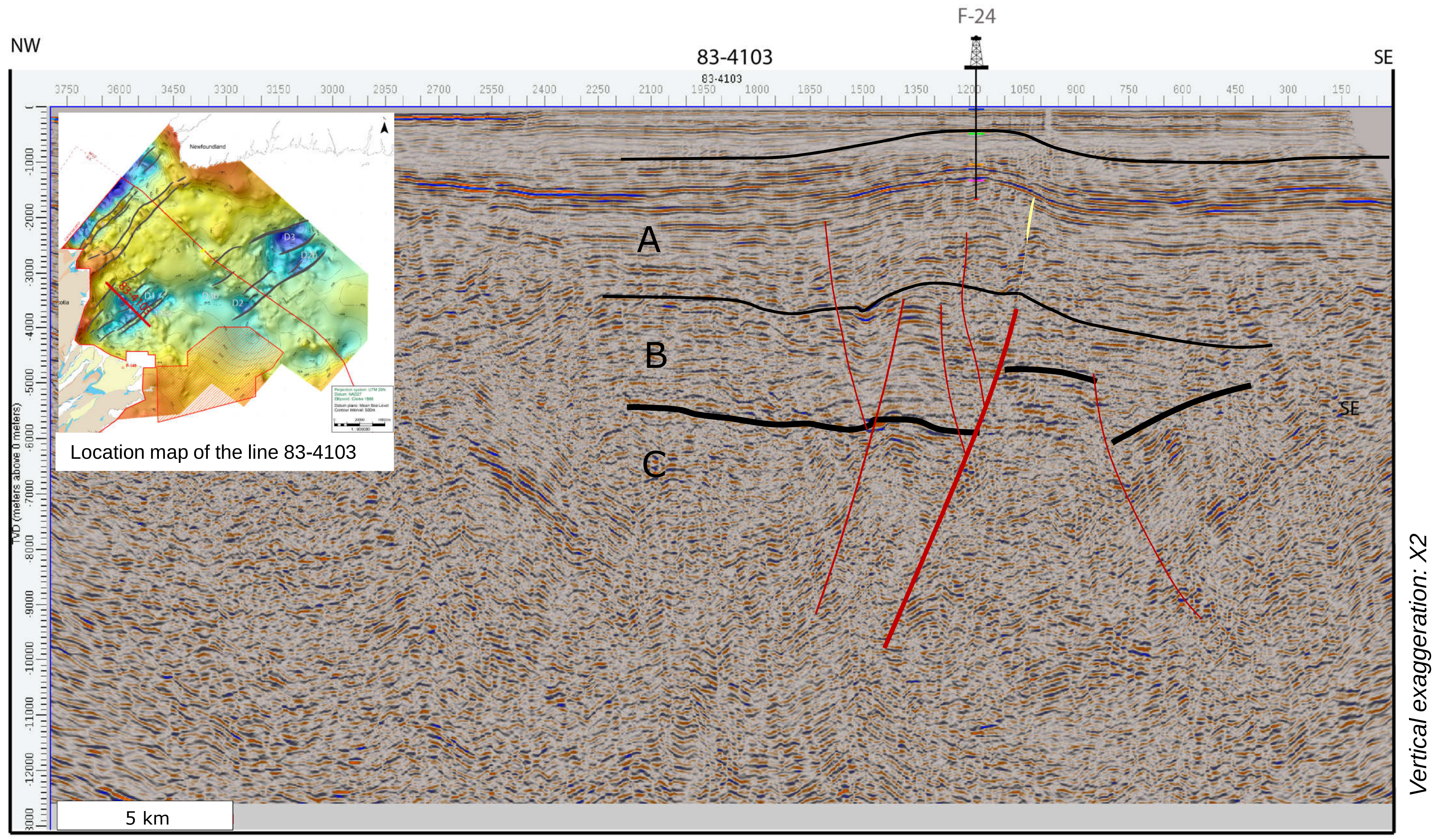
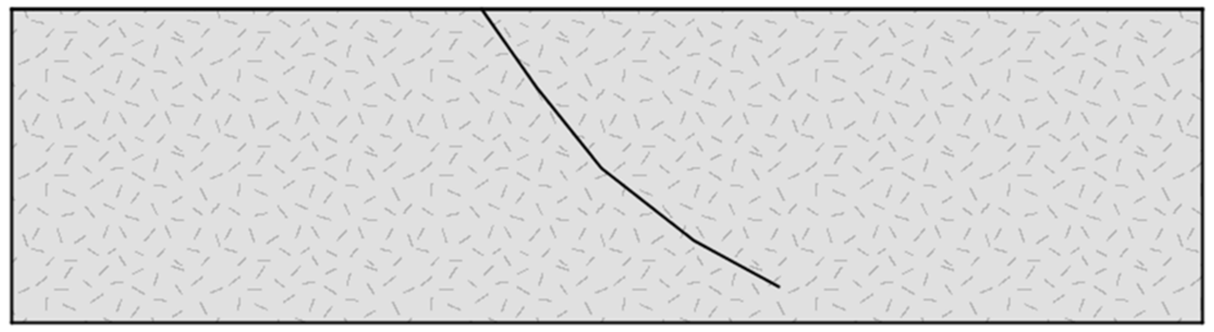


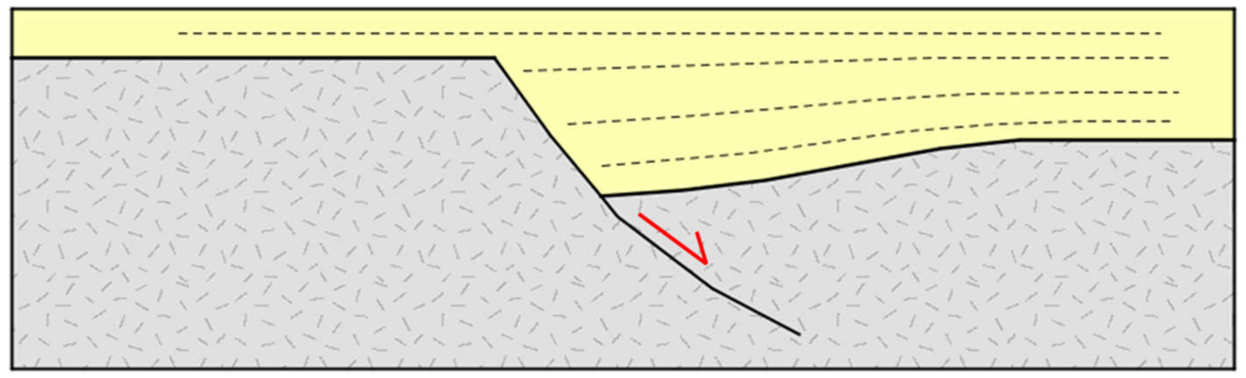
Figure 15: Seismic interpretation of the main kinematic units associated with a tectonic inversion along the line 83-4103 of the Sydney Basin.
This seismic section shows a representative example of the inversion of a semi-graben along the Sydney Basin. The inversion fold is an asymmetric anticline facing the footwall of the fault. The interval C is the pre-rift unit (pre-Carboniferous).
The large thickness variation of the Unit-B (Horton Gp.) highlights a fault-controlled deposition during an extensional (syn-rift) regime. The interval A represents the post-rift unit, characterized by an overall constant thickness. It includes Middle and Late Carboniferous and Permian units.

Figure 16: (from 0 to 6) Schematic Tectonic Evolution of the Sydney Basin.
A schematic and synthetic tectonic evolution of a representative and conceptual cross-section of the Sydney Basin was built in form of sequential forward-modelling, from the pre-Carboniferous basement (0) until the present day (6).
As illustrated by the seven kinematic steps below and the vertical time scale column, the main deformation events affecting the Basin occurred during the Paleozoic.

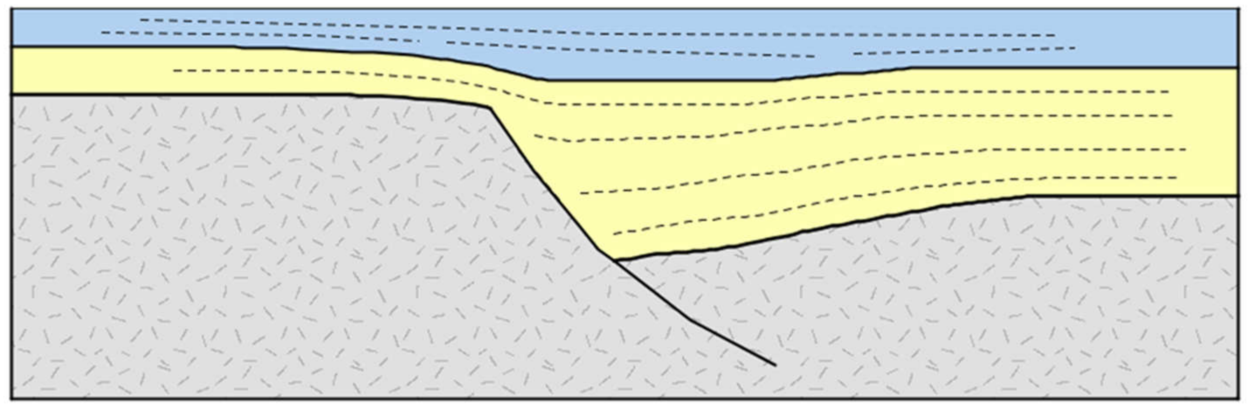
0 Pre-Carboniferous Basement



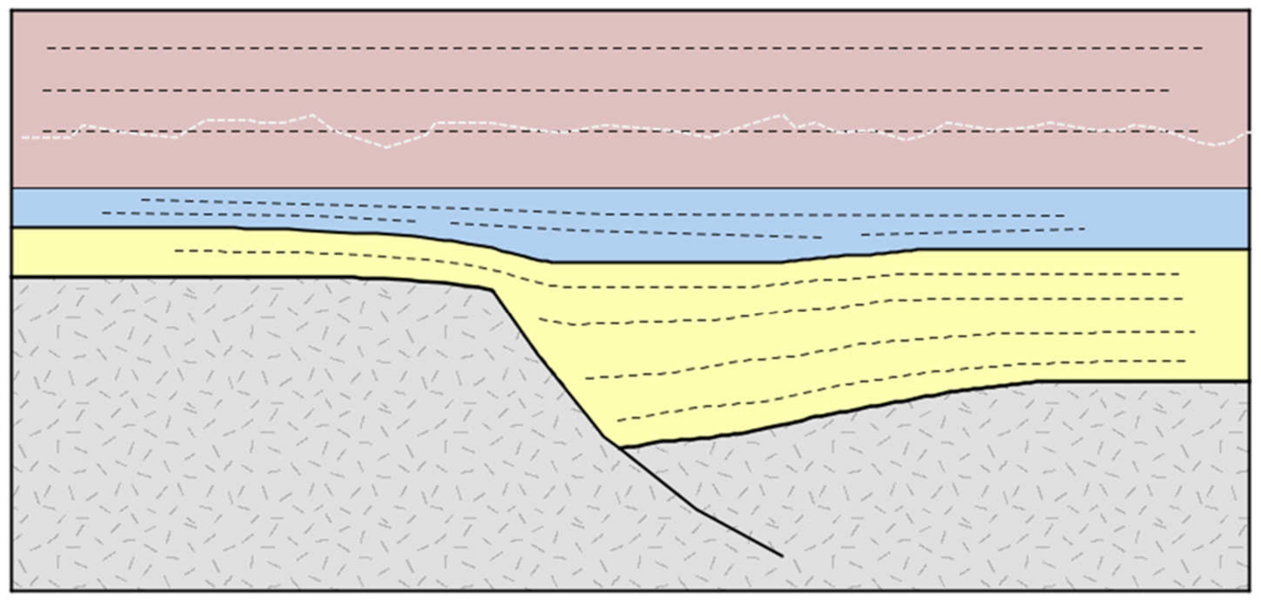
1 An extensional phase (probably transtensional) during the Late Devonian/ Early Carboniferous controlled the deposition of the Horton Group.
Growth strata have been identified on seismic, typical of syn-kinematic deposition.

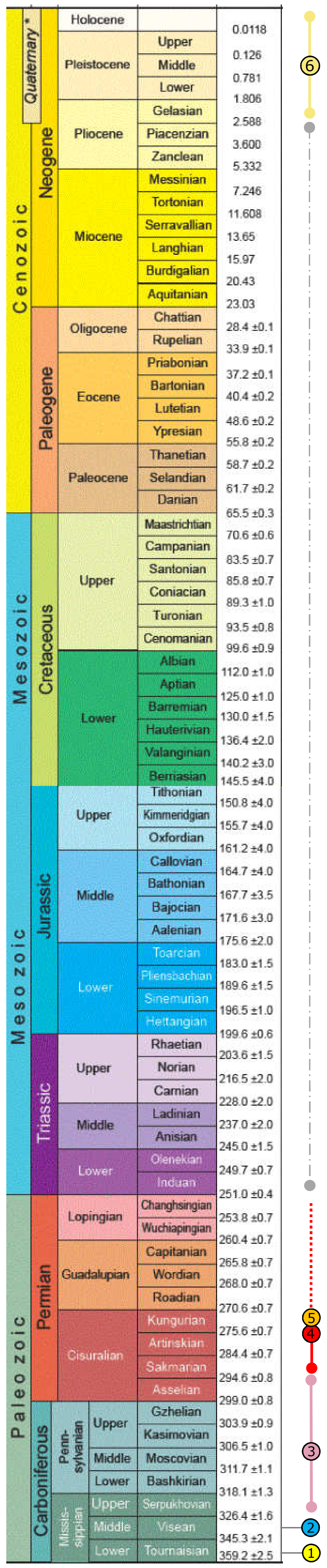


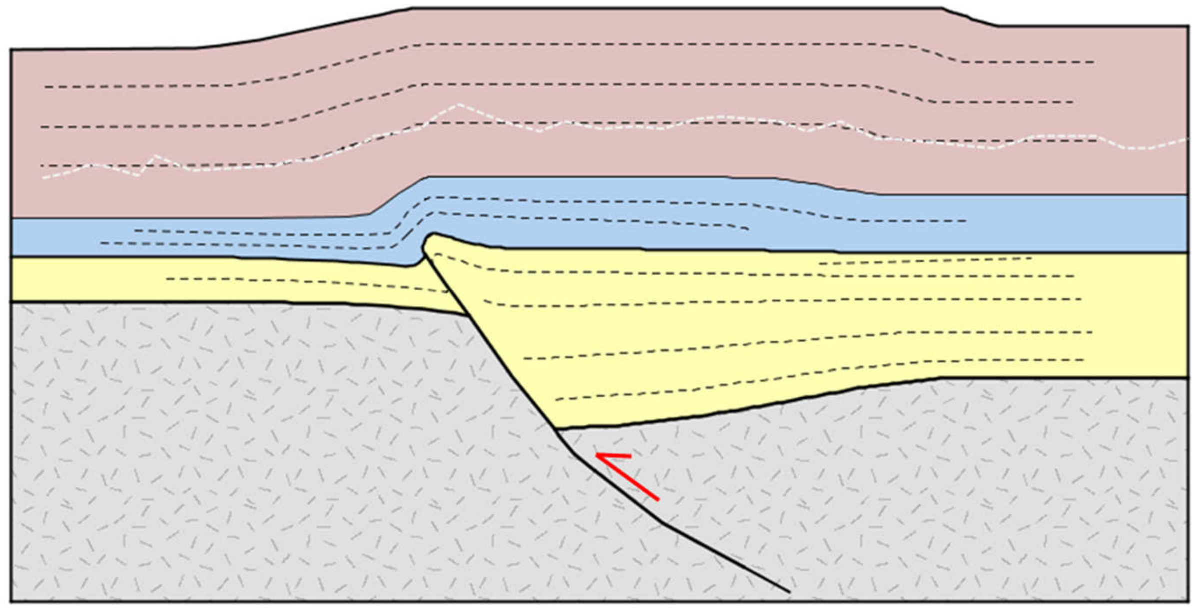
2 The extensional phase (1) was followed by a period of subsidence and local minor extensional activity that controlled the deposition of the Windsor Group (Middle Carboniferous).



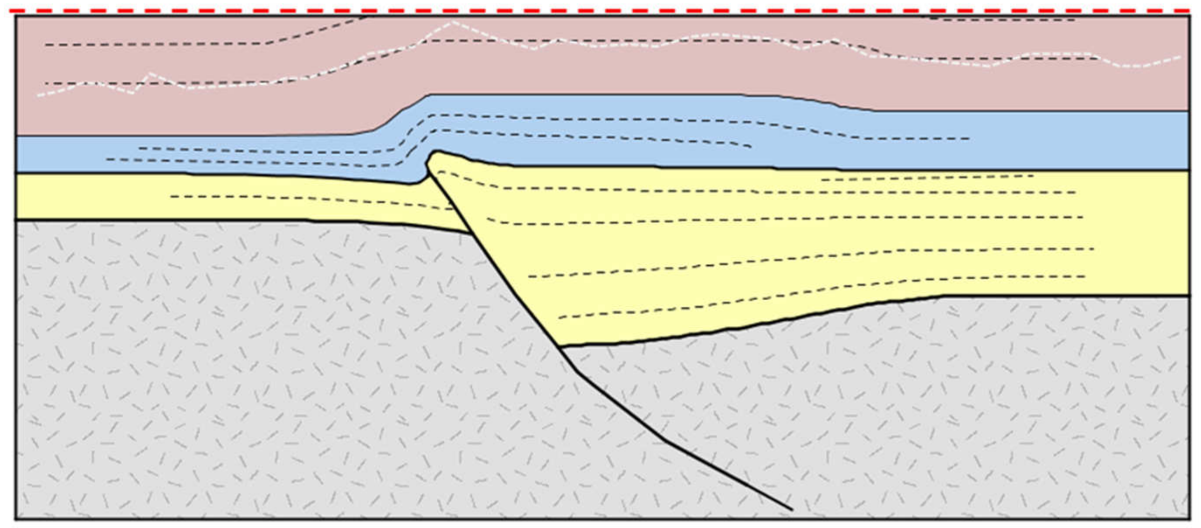
3 The Late Carboniferous and Permian deposition (Mabou Gp., Morien Gp. and Pictou Gp.) was mainly affected by large subsidence. Several erosional surfaces are identified in this tectonic unit, typical of a continental depositional environment. The most relevant unconformity is the Namurian (grey dotted line), identified both on well and seismic data.



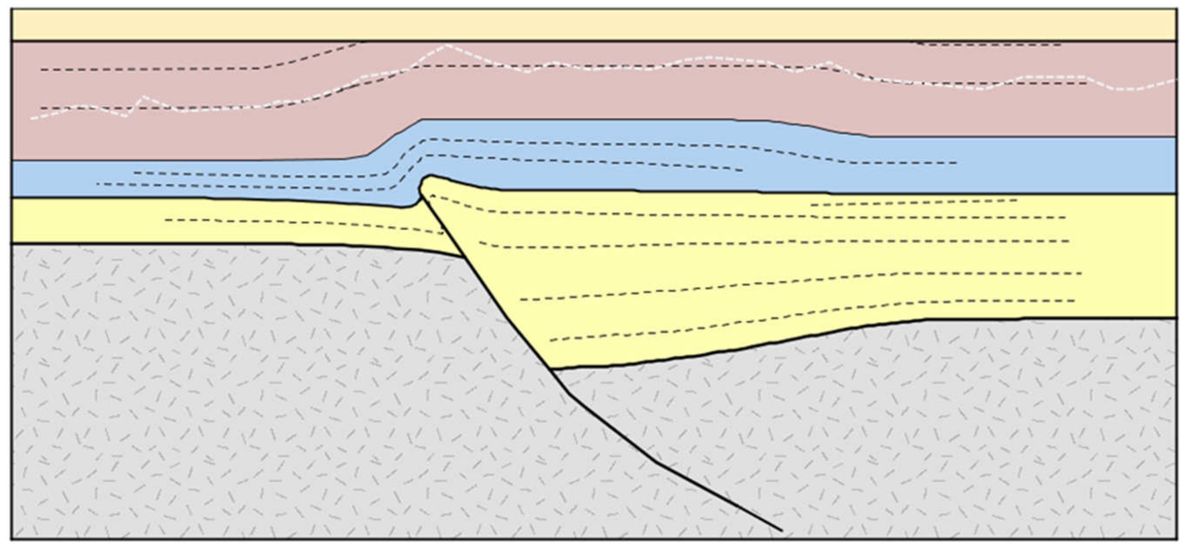




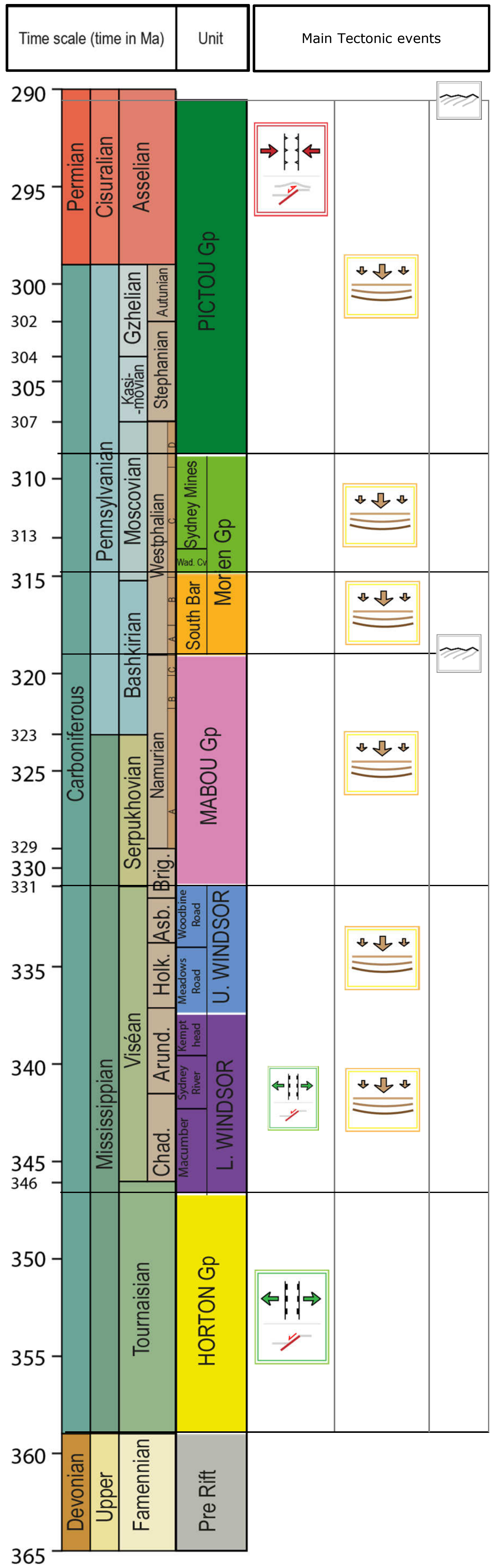
4 The entire Carboniferous and Permian sequence was affected by a regional transpressional phase. The pre-existing normal faults were locally inverted.
Positive structures were formed during this phase with a fault propagation fold mechanism. A representative example along the Sydney Basin is the North Sydney fault.
Seismic evidence allowed defining the Late Asselian, (294 Ma) as the lower age limit of this tectonic event.
The data do not allow definition of the upper age limit but it is geologically reasonable to assume this to be related to the Hercinian orogeny, active until the Late Permian.



5 An erosional event occurred after the creation of the positive reliefs due to the Lower Permian inversion. The 1D Basin Modeling performed by Beicip-Franlab would suggest up to **~1500/2000 m** of eroded sediments (See chapter 8).



6 The Permian interval is unconformably covered by few hundreds meters of Quaternary sediments.



Line 83-4103

The line 83-4103 crosses the westernmost portion of the Sydney Basin, intersecting the North Sydney fault zone. Well F-24 is located 2km NE of the section.

The interpretation of the Pictou Gp, Sydney Mine Fm., South Bar Fm., and West Namurian unconformity were constrained with well data.

This area of the Sydney Basin is characterized by a system of graben and semi-graben, opened under a transtensive regime during the deposition of the Horton Group (Middle Devonian/Lower Carboniferous).
The Horton Gp. thickness varies from 0.3 to 3.5 km.

The North Sydney anticline is the result of an inversion of the North Sydney fault under a transpressive regime during the Lower Permian age (?).

Regarding the regional significance of the compressional event, this transect shows that its impact remains limited on the Carboniferous succession.

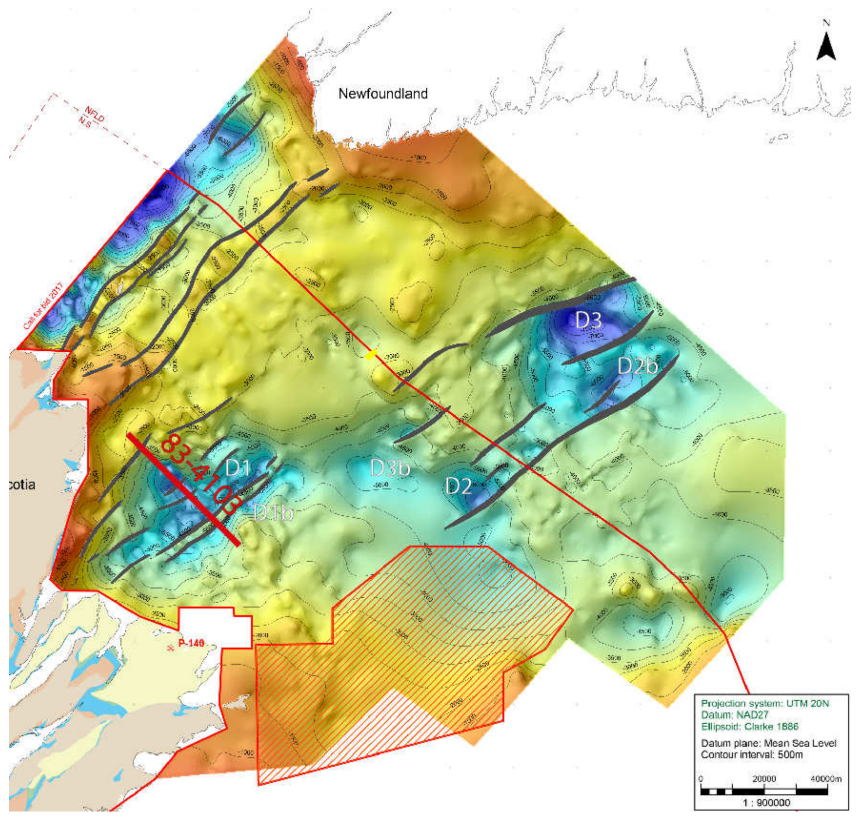
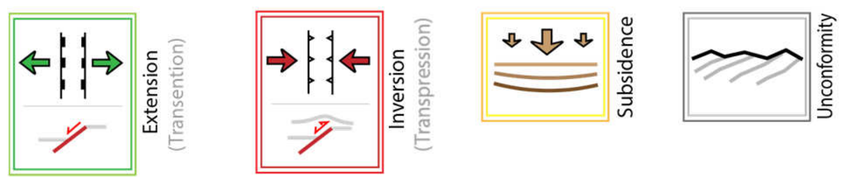


Figure 17: Structural map of the basement and location of seismic line 83-4103 in red.

Legend



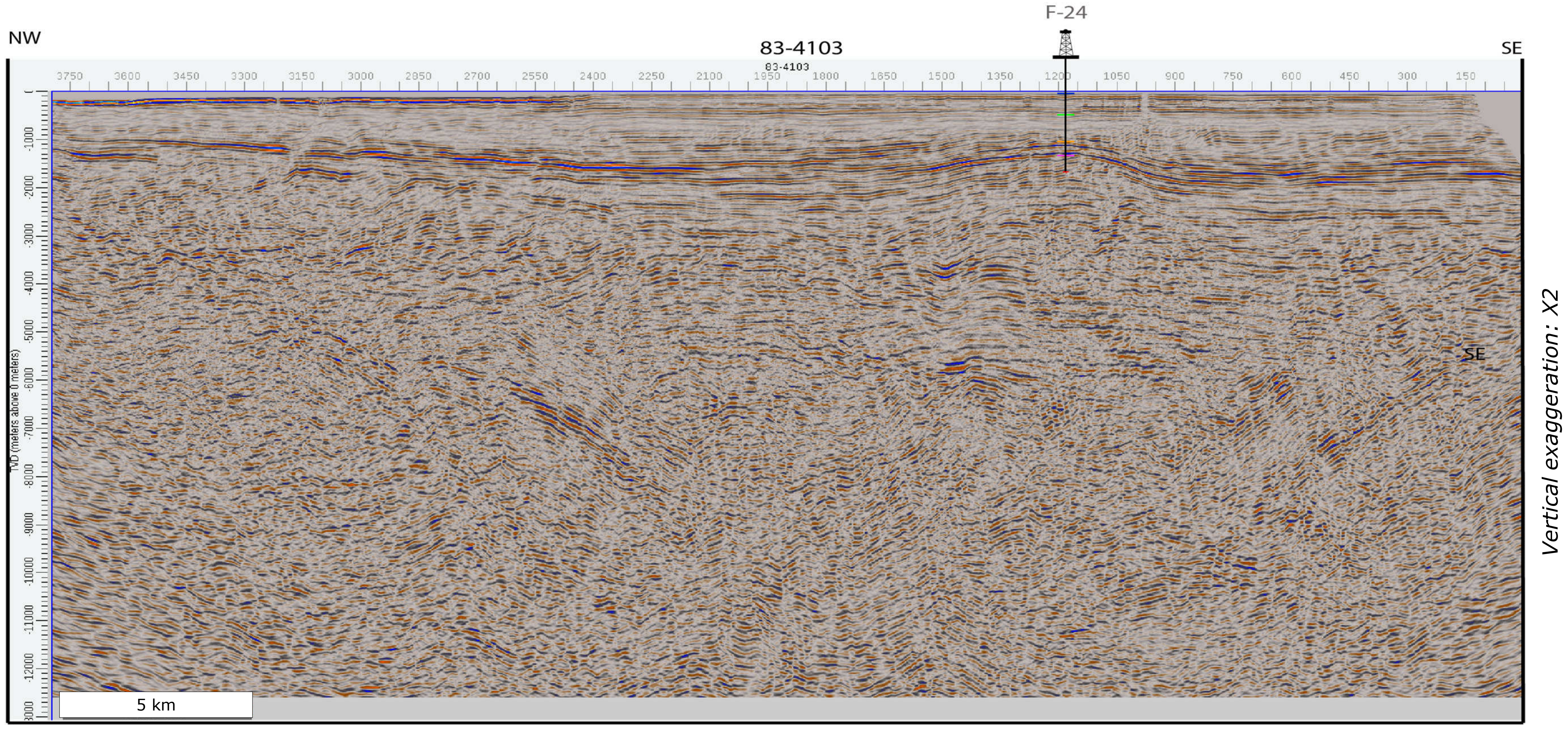


Figure 18: Seismic line (TVD) 83-4103

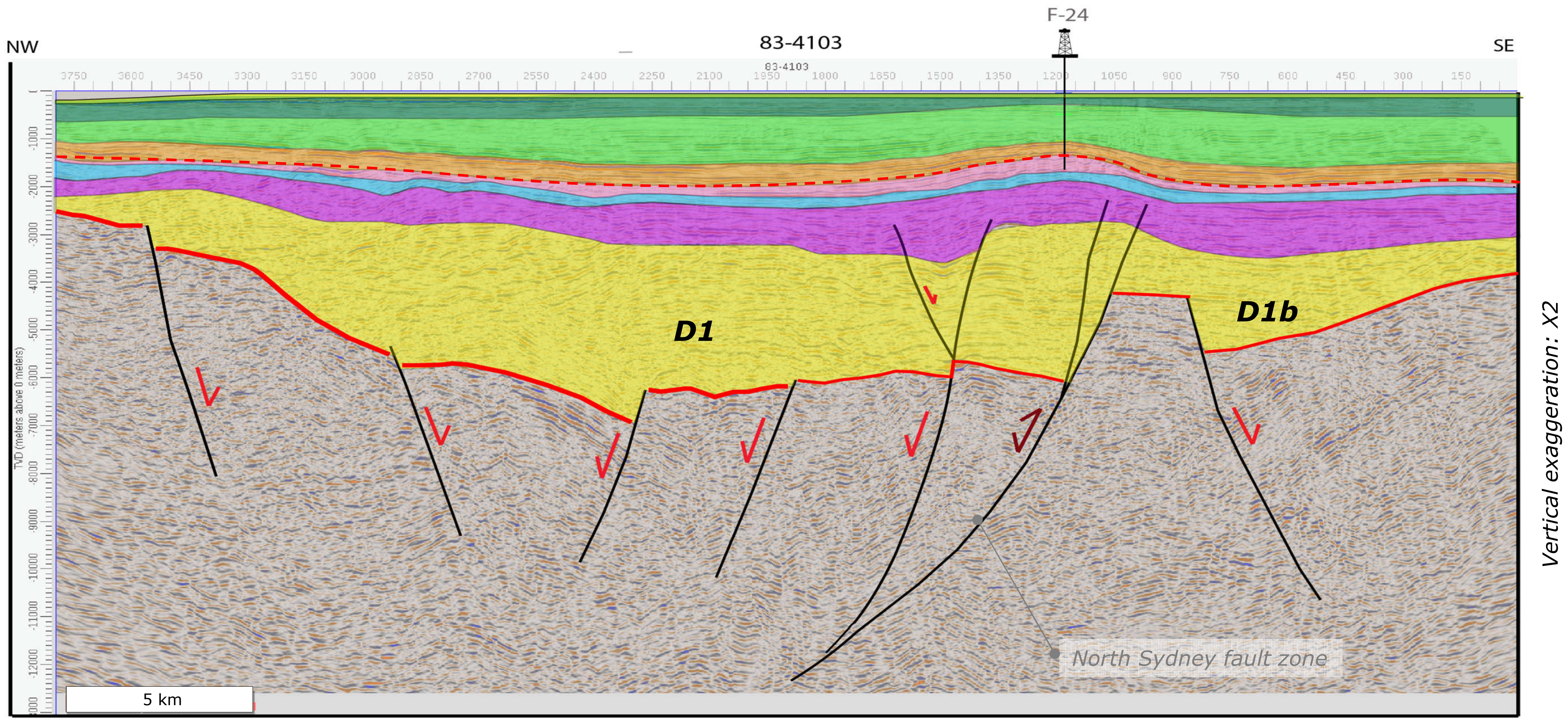
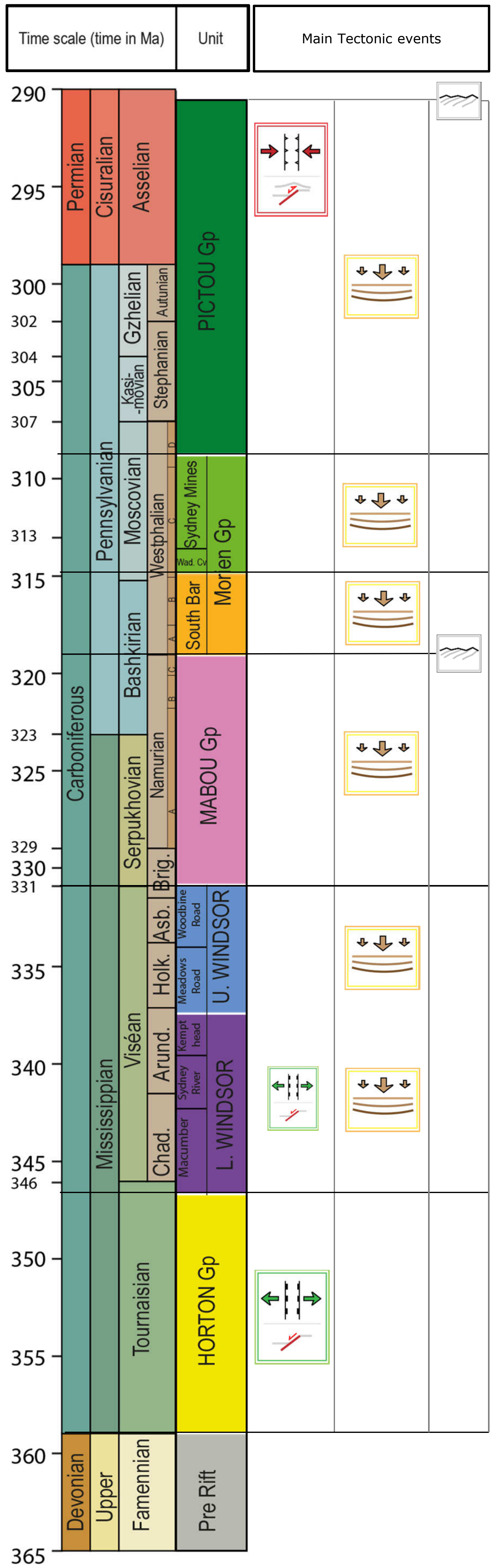


Figure 19: Geological interpretation of seismic line (TVD) 83-4103

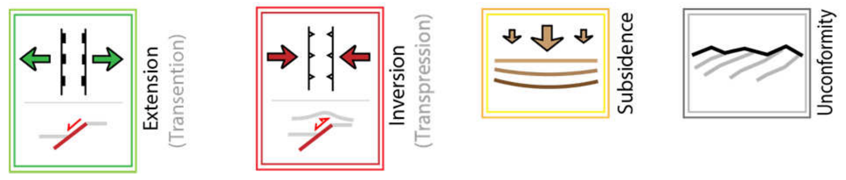


Composite line 4 + K50

The composite line 4 + K-50 crosses most of the Sydney Basin, from the Cabot Fault zone on the left hand-side of the section, to the depocenter D2.
The Horton is clearly fault-controlled by the transtensional event of Lower Carboniferous age that formed a semigraben system, with typical rotated blocks and growth strata. The deepest semi-graben of this section is D2, which reaches ~6150 m (TVD).

This transect clearly shows elements of tectonic inversion, analogue at the North Sydney fault, along the line 83-4103.
The three smooth fault-related anticlines (identified by grey arrows in the section view) are the result of a transpressional stress field (during the Permian?), where the pre-existing normal faults have been re-activated with inverted kinematic. The effect of the inversion is represented by the folding of the post-rift series (Windsor, Namurian, Sydney Mine and Pictou Gp.) with a typical fault bend fold deformation mechanism. It's to be noted that although the inversion is a major tectonic event, this part of the basin remains relatively protected form the compression.

Legend



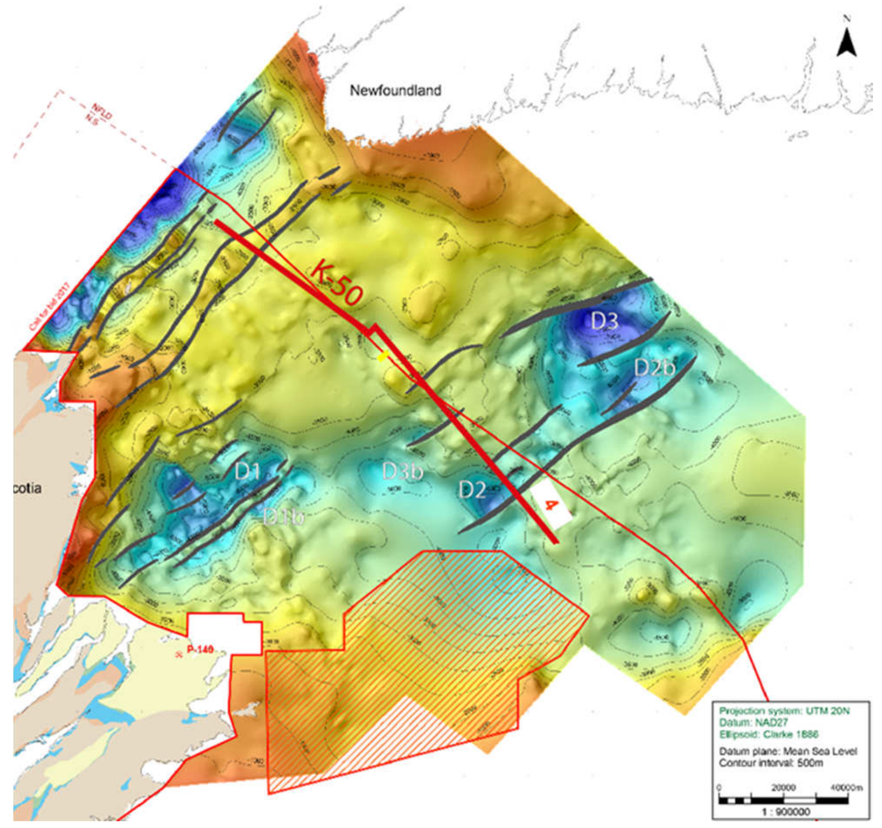


Figure 20: Structural map of the basement and location of composite seismic line 4 + K50 in red.

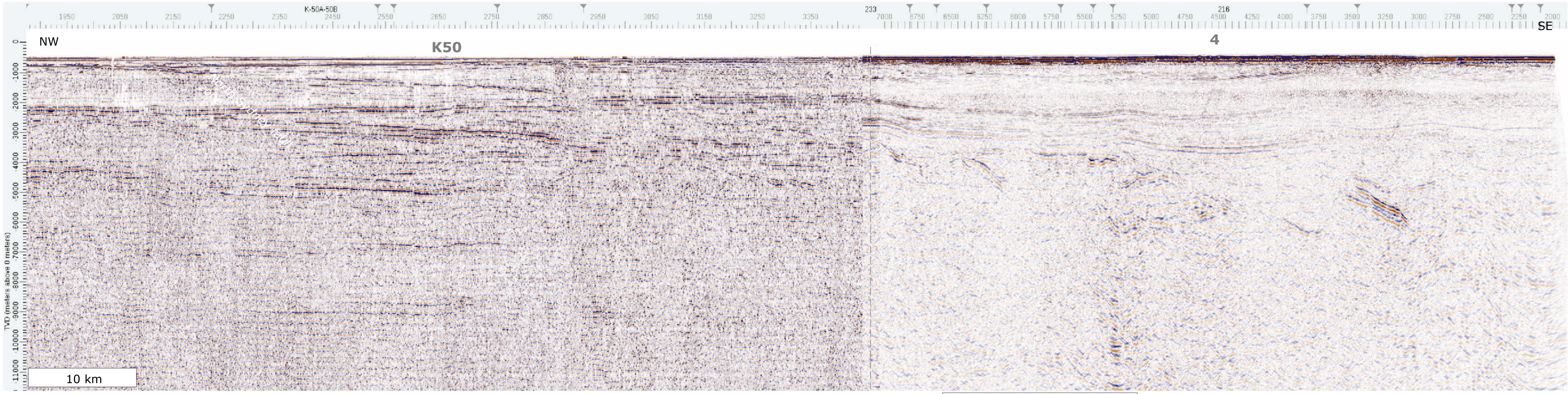


Figure 21: Composite seismic line (TVD) 4 + K50

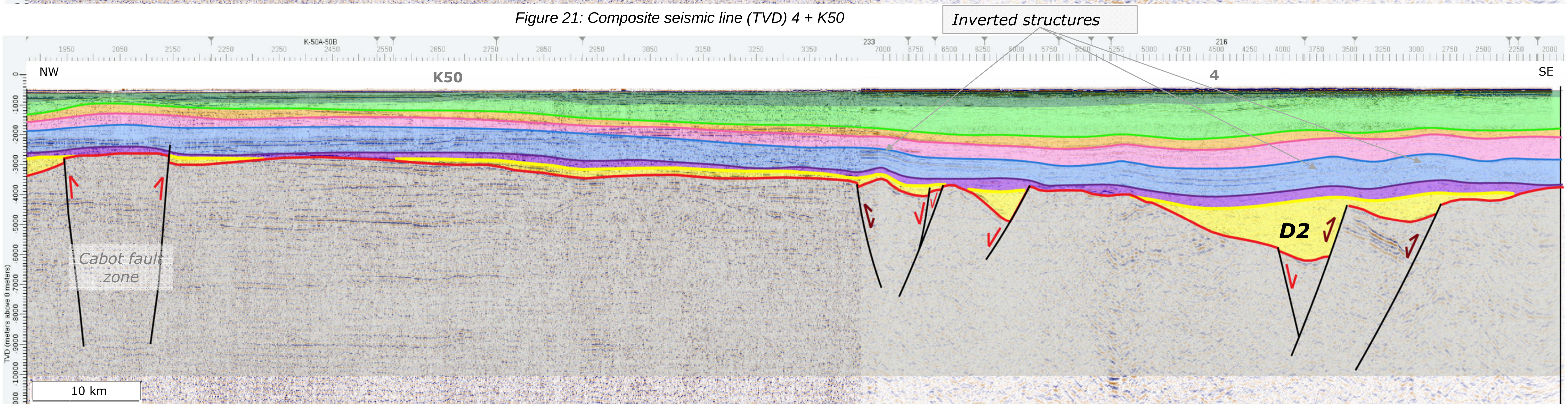
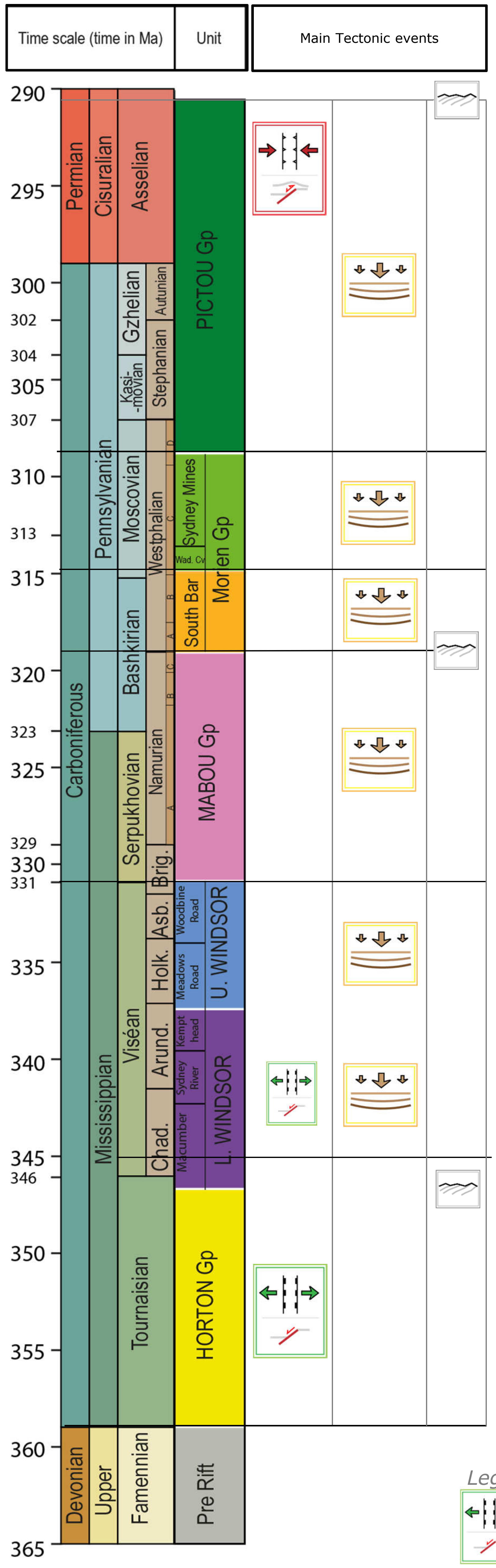
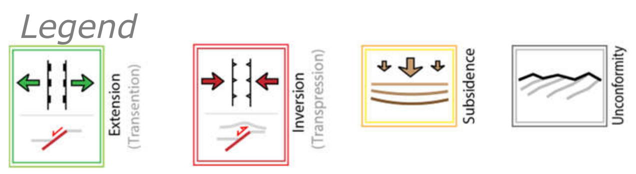


Figure 22: Geological interpretation of composite seismic line (TVD) 4 + K50

Geological interpretation of composite seismic line (TVD) 4 + K50





Line 1

Line 1 crosses the most north-eastern portion of the Sydney Basin, intersecting a graben that defines the depocenter D3 and a semigraben verging towards the right-hand of the section (SE) that defines the depocenter D2b.

As shown in Figure 23 this seismic section reveals strong and truncated reflectors between 5000 and 7000 m in the central area; these were interpreted as pre-rift units, strongly deformed by pre-carboniferous tectonic events (Pl. 2-4, 2-5).
The Horton is clearly fault-controlled by the transtensional event of the Lower Carboniferous. As showed in figure 23, similarly to the pre-rift units, the Horton reflectors are deeply eroded; a clear angular unconformity is present on the northernmost boundary of the D3 basin; this would suggest local inversion after the deposition of the Horton Gp. but before the deposition of the Windsor Gp.

In addition, this transect clearly shows elements of tectonic inversion, confirming that the transpressional phase affected all the main depocenters of the Sydney Basin (D1, D2, D2b and D3).

The smooth fault-related anticlines identified by grey arrows in section view are the result of a transpressional stress field (Permian?); the pre-existing normal fault have been re-activated with inverted kinematic. The effect of the inversion is represented by the folding of the post-rift series (Windsor, Namurian, Sydney Mine and Pictou Gp.).
As for the transect in plate 2.2.4, It's to be noted that this part of the basin remained relatively protected form compression.

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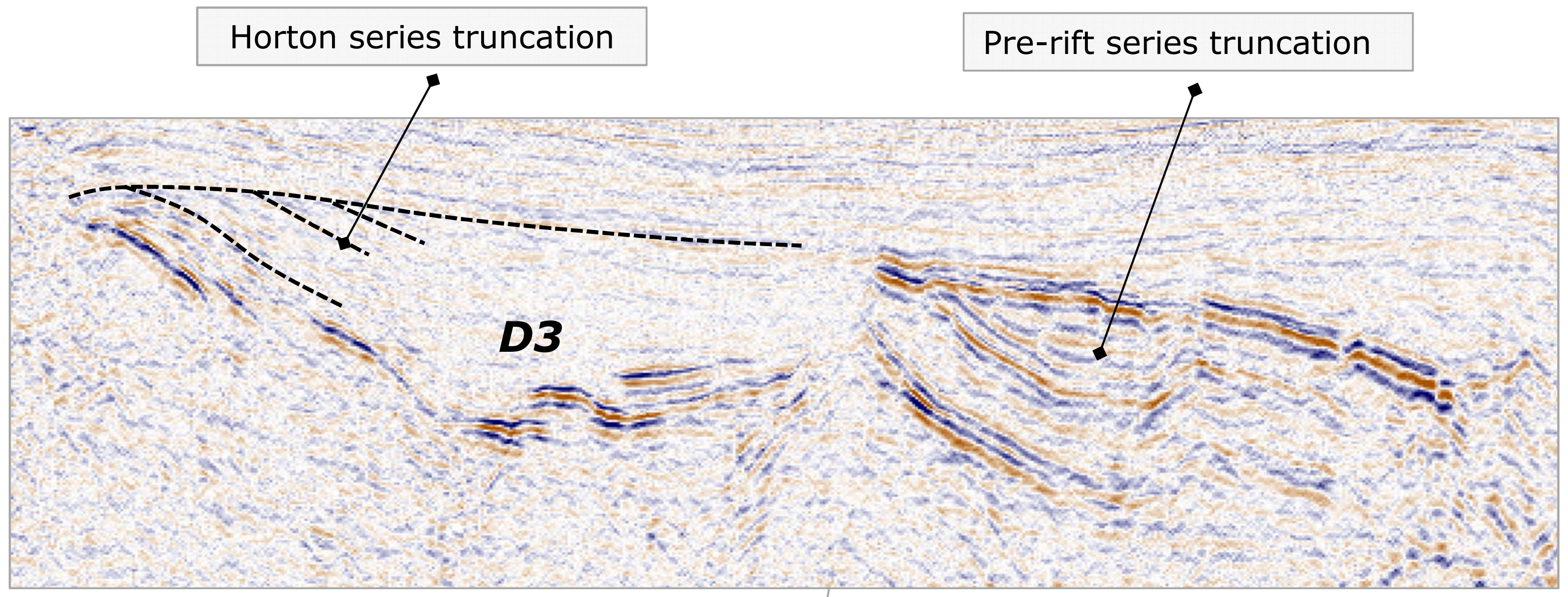


Figure 23: Zoom of the seismic line 1, highlighting geological truncation.

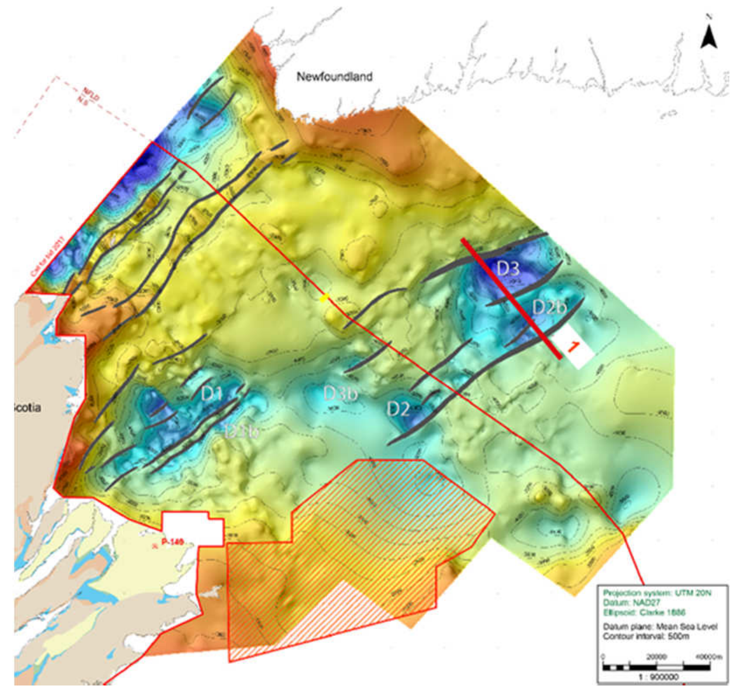


Figure 24: Structural map of the basement and location of seismic line 1 in red.

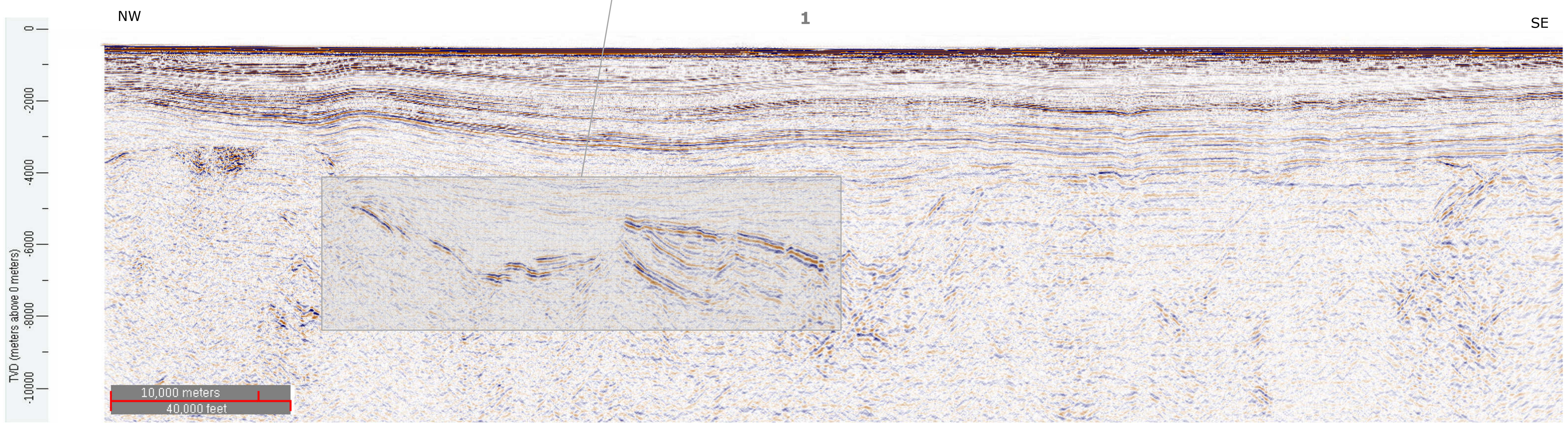


Figure 25: Seismic line (TVD) 1

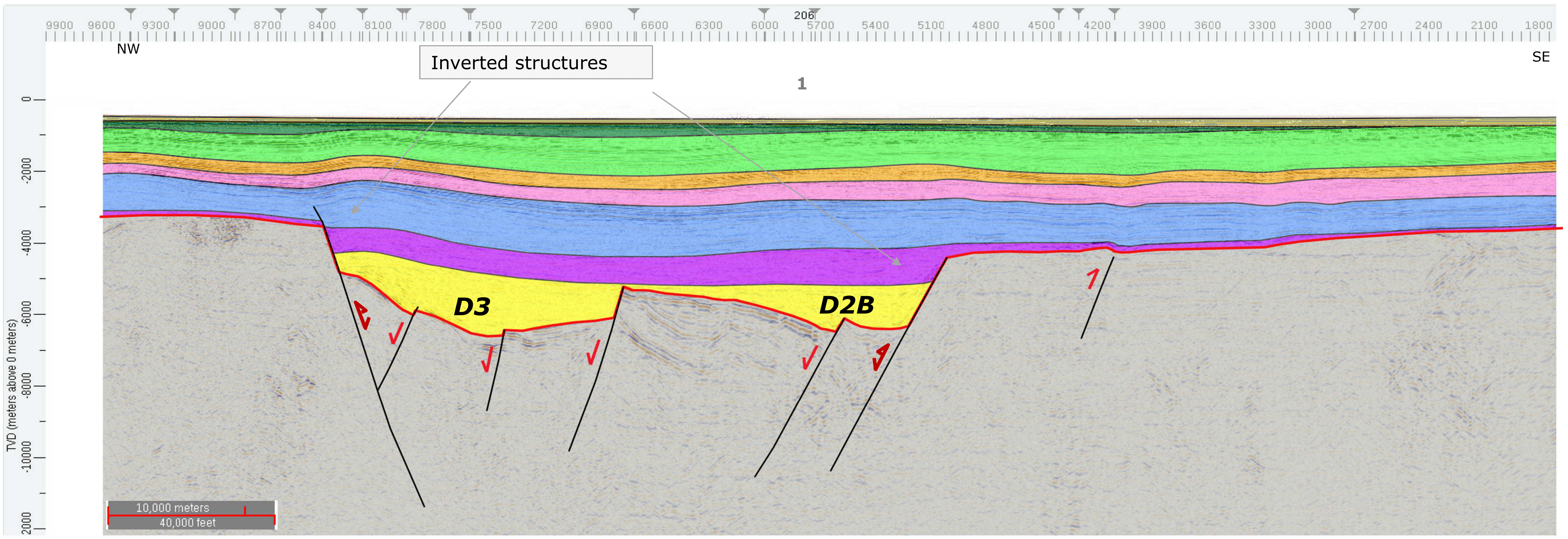
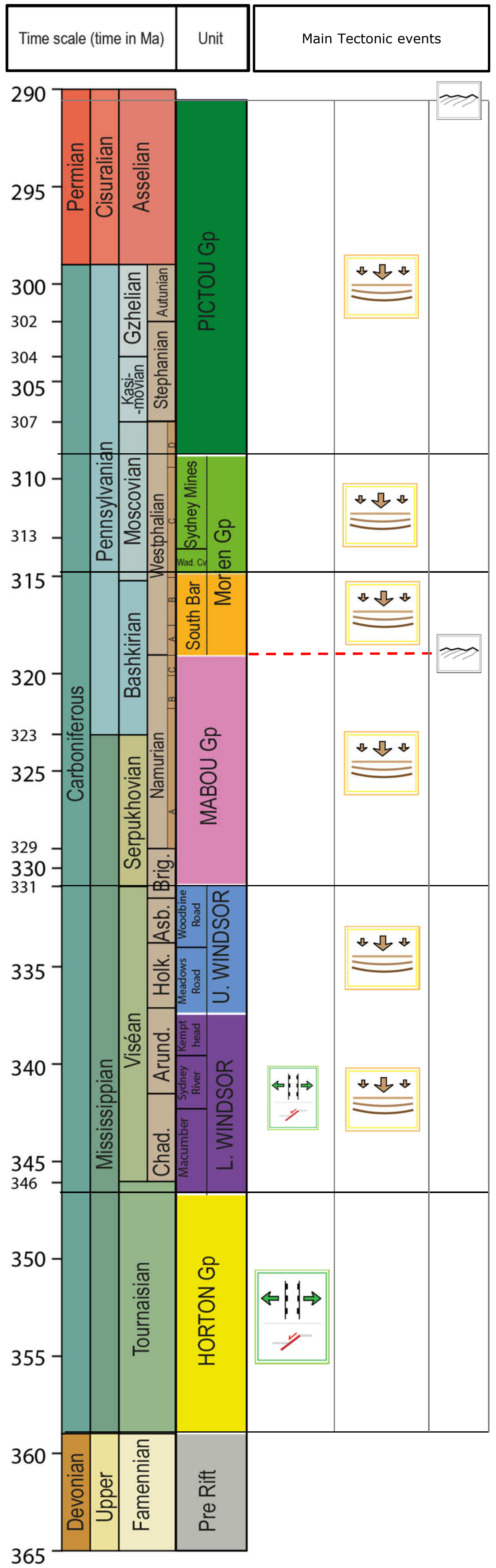


Figure 26: Geological interpretation of seismic line (TVD) 1



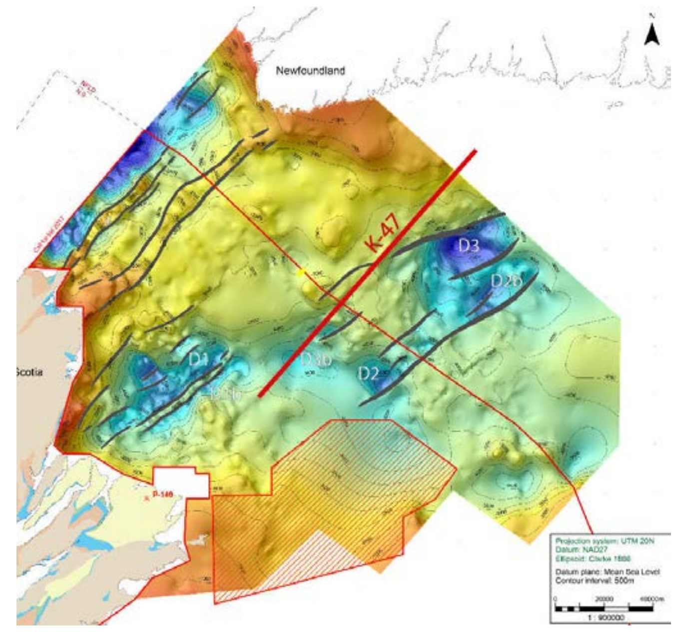
Line K-47

Line K-47 crosses the Sydney Basin longitudinally to the main fault trend (NE-SW).
Due to the direction of the cross-section, no major fault zones are intersected and the thickness of the main units are generally constant.

The Horton Gp. is present in the left hand side of the section only (depocenter D3b), suggesting the presence of a paleo-depocenter due to subsidence and local extension (transtension) in this area.

The rest of the series was deposited under a subsidence regime with local transtension that defined local fault controlled deposition.

Legend



Structural map of the basement and location of seismic line K-47 in red.

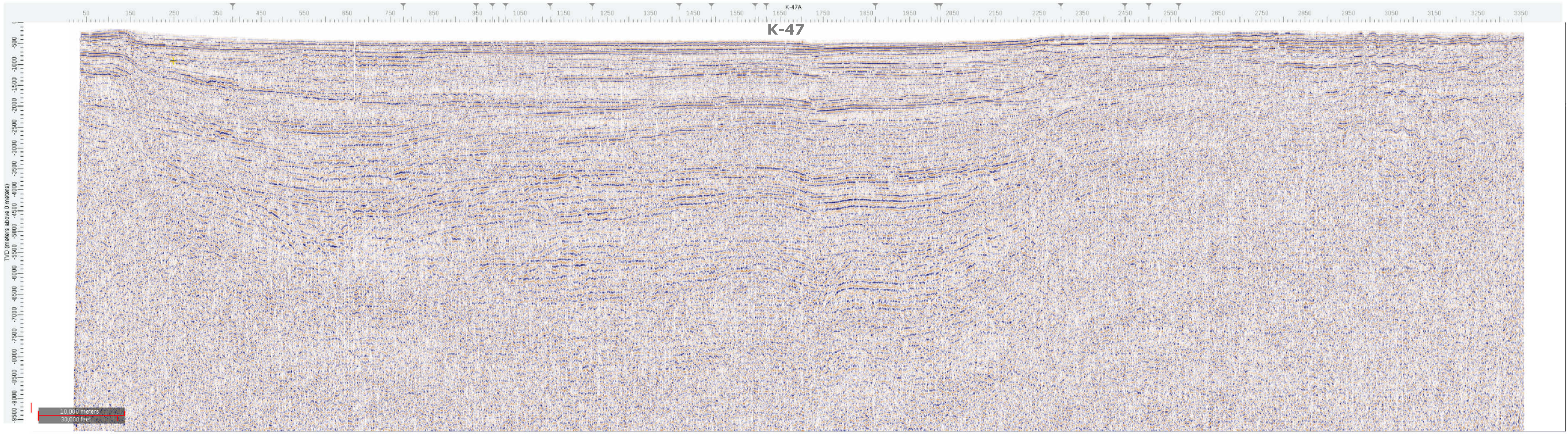


Figure 28: Seismic line (TVD) K-47

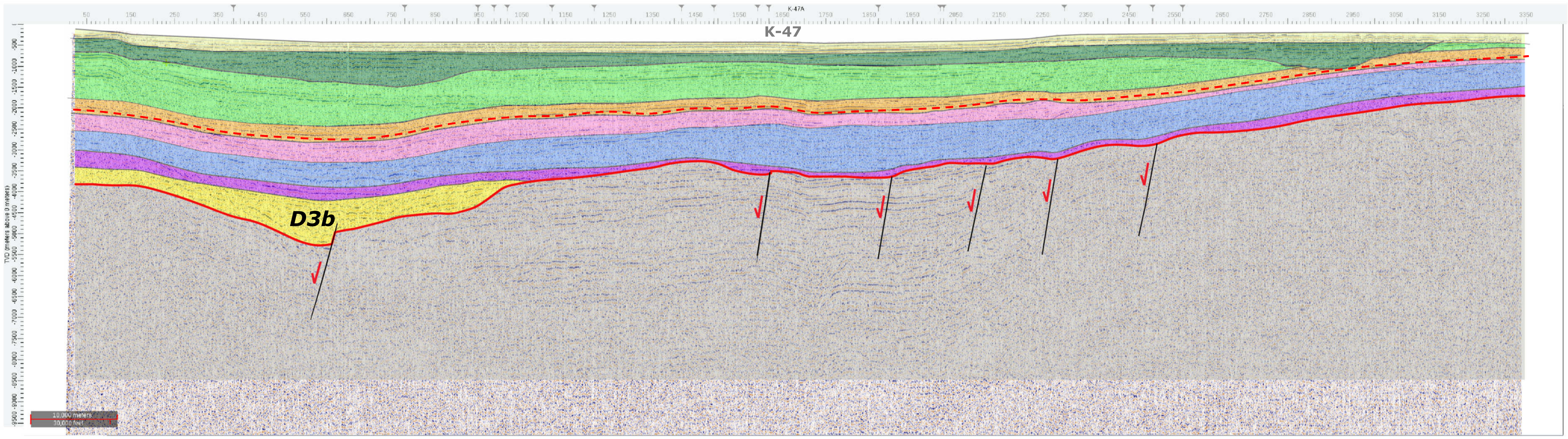


Figure 29: Geological interpretation of seismic line (TVD) K-47

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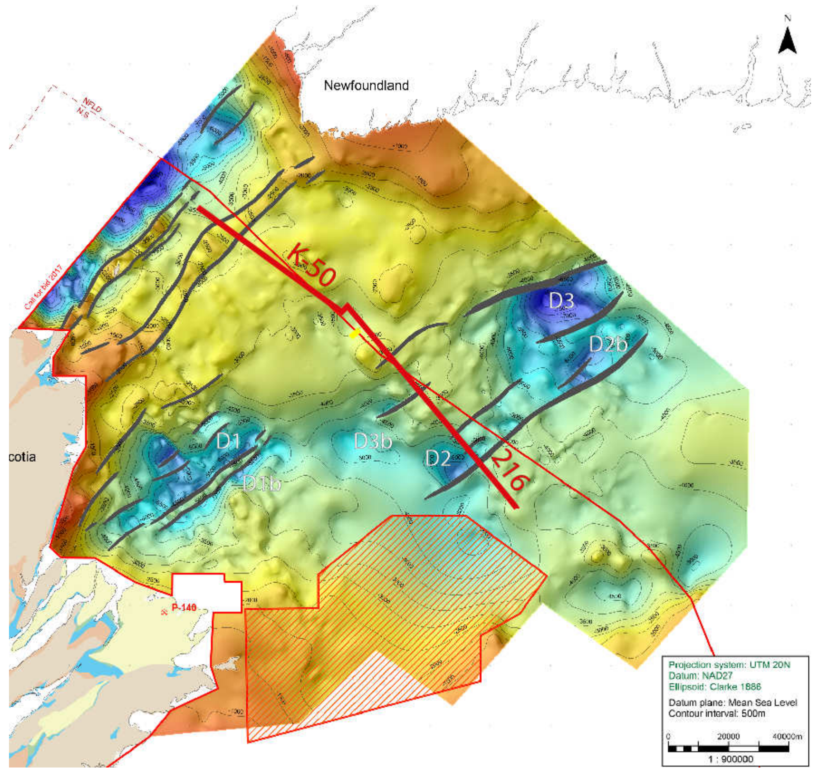
Geological interpretation of seismic line (TVD) K-47



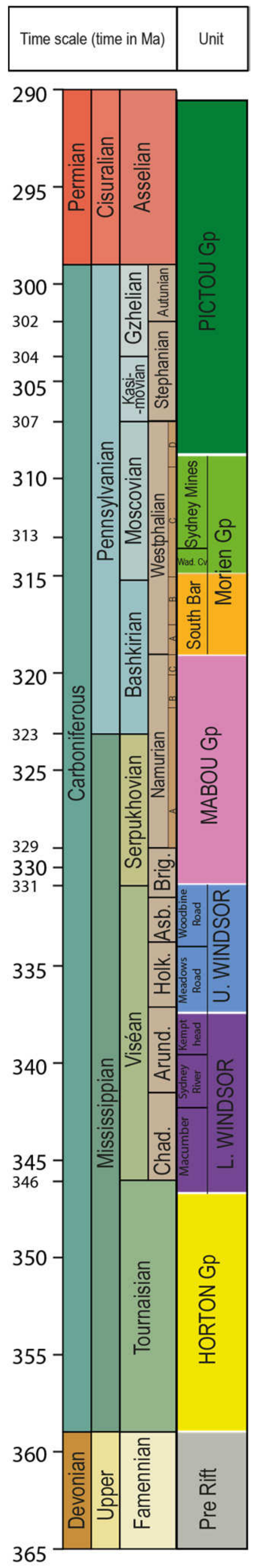


Figure 30 (Step-1 – Step-10) Sequential Restoration of the composite seismic line 4 + K50.

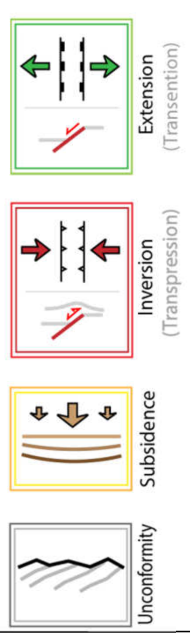
The sequential restoration illustrated below from the Present day (Step-1) to the Pre-Carboniferous (Step 9) shows the main tectonic events affecting the primary depocenters of the Sydney Basin.

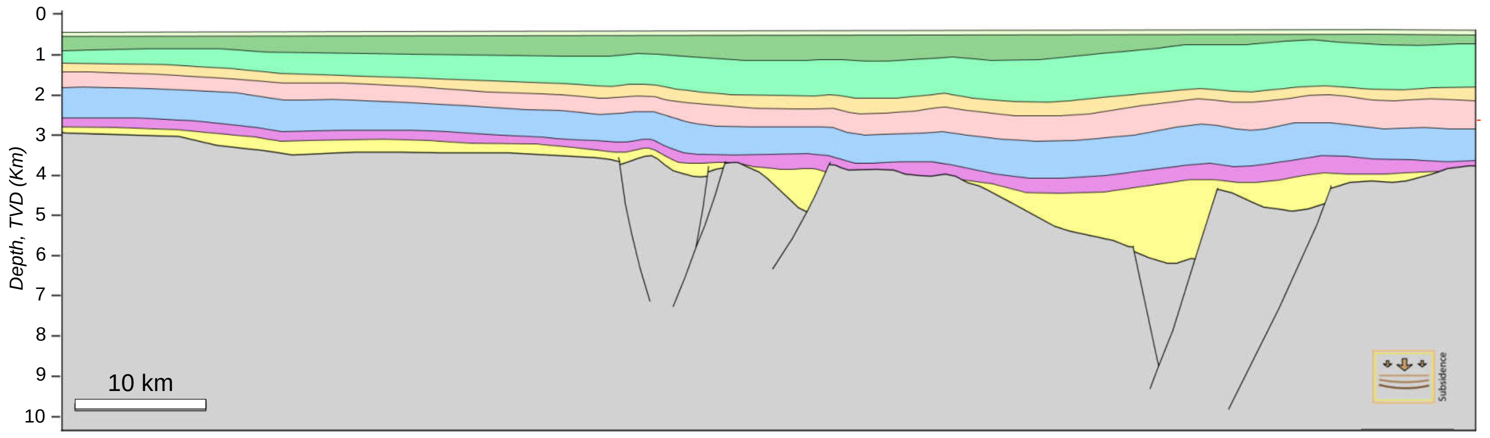
This composite line (4+K50) crosses the central area of the Sydney Basin, revealing a half-graben system, with typical rotated blocks and growth strata.
This transect clearly shows elements of tectonic inversion, analogous to the North Sydney fault, along the line 83-4103.

The four smooth fault-related anticlines arrowed in red in Step 2 are the result of a transpressional stress field (during the Permian?), where the pre-existing normal faults have been re-activated with inverted kinematic.

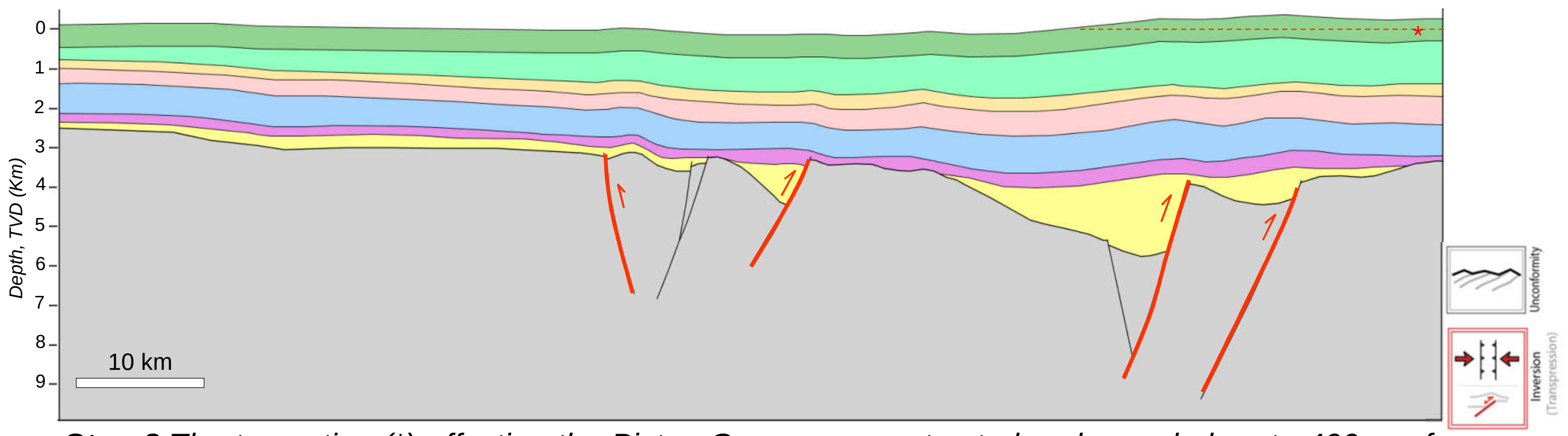
The back-stripped sections cannot be considered fully balanced because of the out-of plane movements due to the lateral displacement component, in both transtensive and transpressive regimes.

Legend

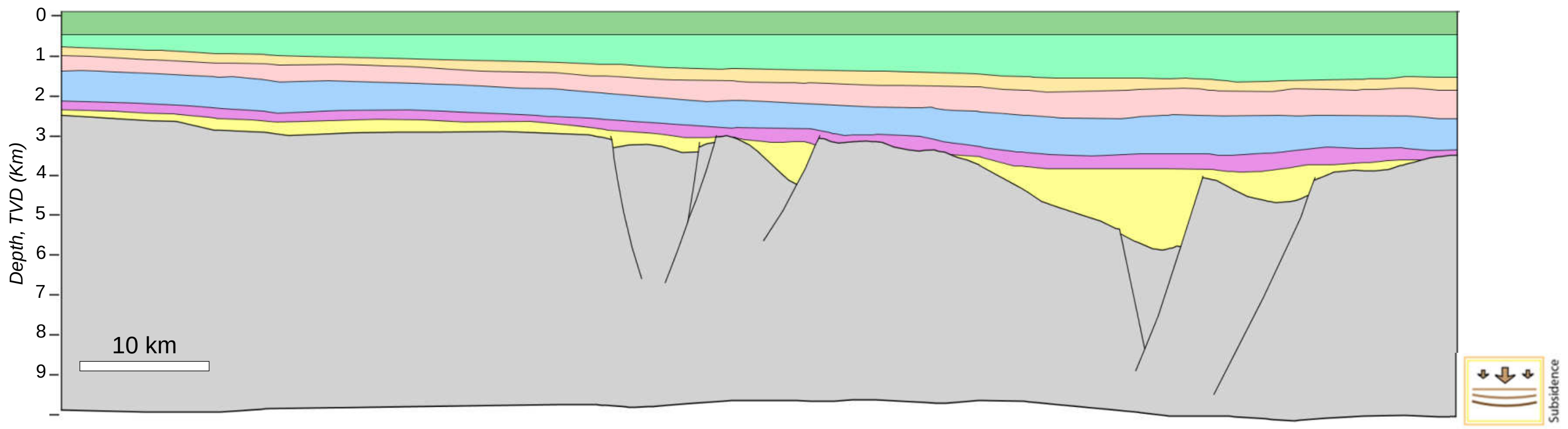




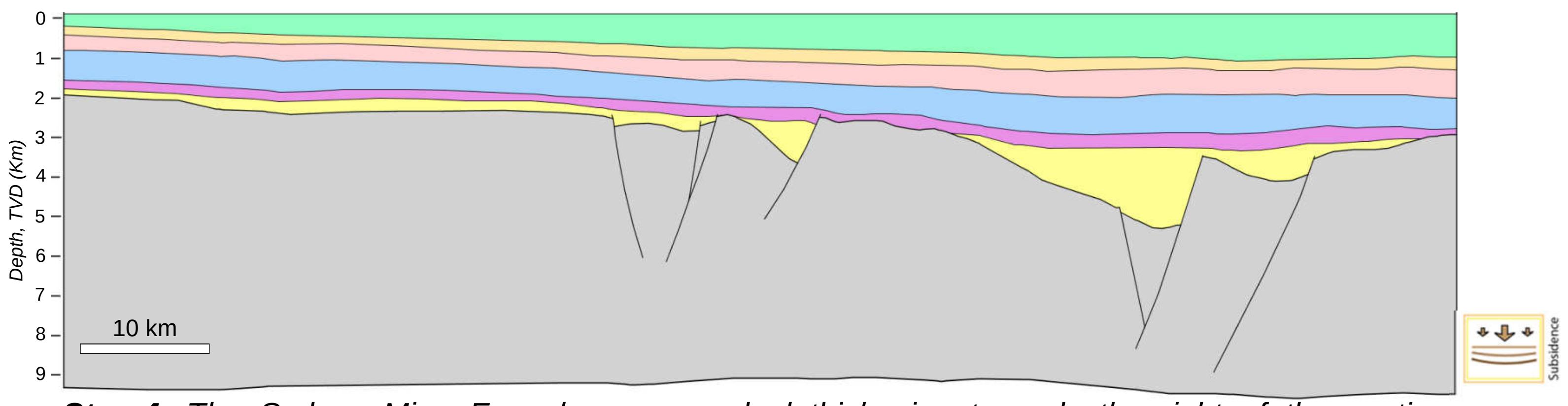
***Step-1**. Present day: few hundreds meters of recent sediments cover the Pictou Gp.*



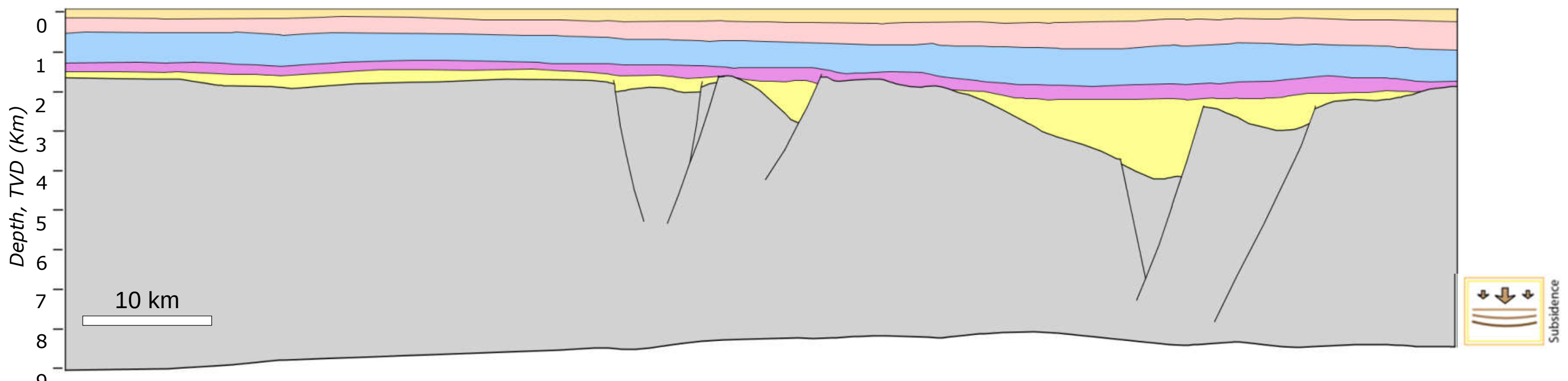
***Step-2.**The truncation (*) affecting the Pictou Gp was reconstructed and revealed up to 400 m of eroded sediments. The reconstruction shows four smooth antiforms that were the result of the Inversion of pre-existing normal fault (Early Carboniferous) active under a transpressive regime active during the Permian age (?)*



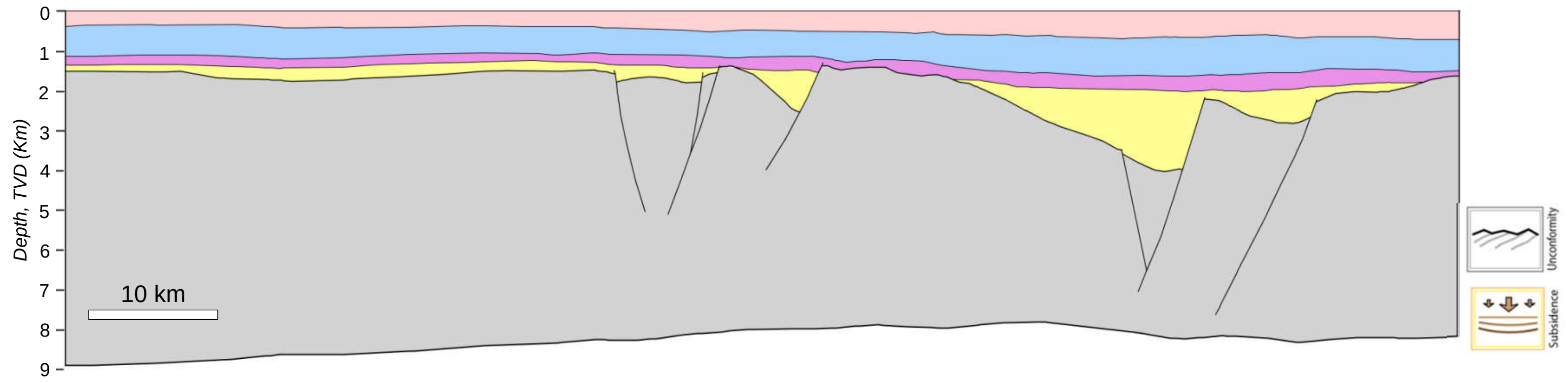
***Step-3**. The Permian (?) inversion (transpression) phase is restored. All the fault-related anticlines are back-stripped. The constant thickness of the Pictou Gp. suggests no relevant deformation events controlling the deposition.*



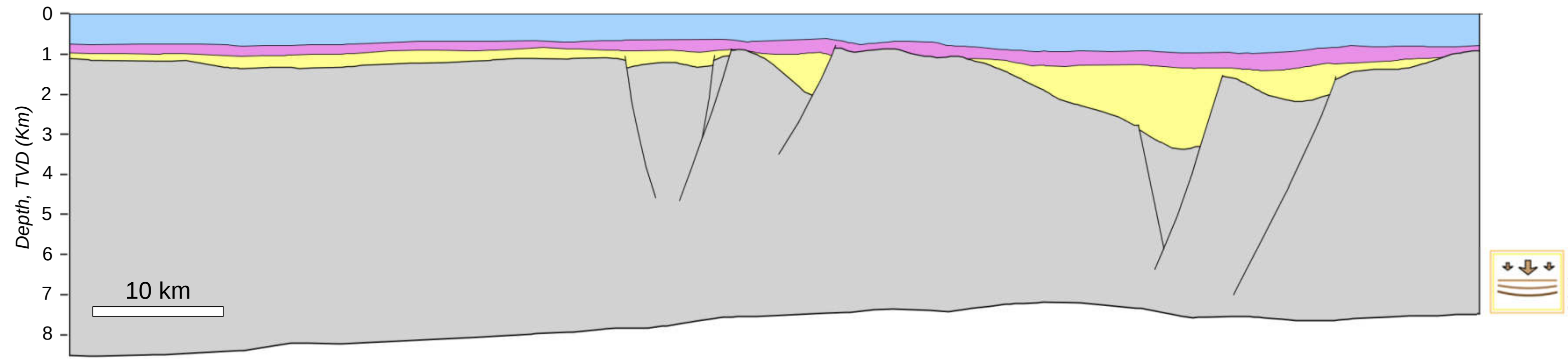
***Step-4**. The Sydney Mine Fm. shows a gradual thickening towards the right of the section (towards SE), and suggests subsidence with a main focus in the south area. No relevant fault activity is recorded during this period.*



***Step-5**. The constant thickness of the South-Bar Fm. suggests no relevant deformation events during this period.*

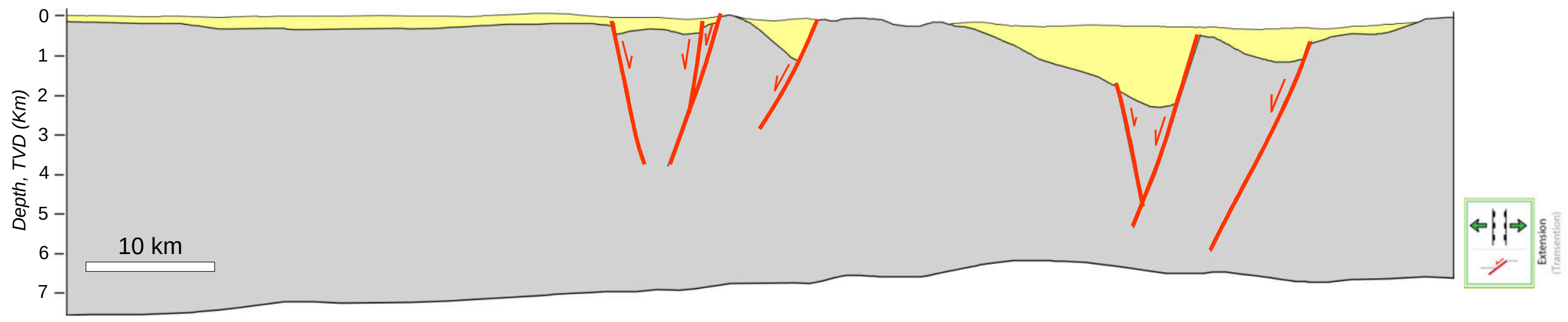


***Step-6**. The Namurian unit shows a gradual thickening towards the right of the section (towards SE), most likely due to subsidence in the south. No relevant fault activity is recorded during this period. The Top Namurian represents one of the major unconformities of the area, verified on both well and seismic data.*

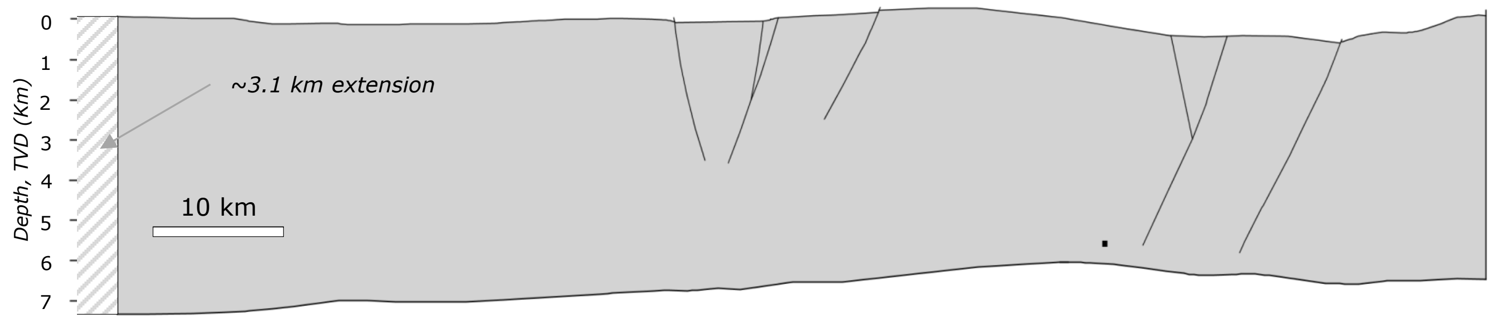


***Step-7**. The constant thickness of the Upper Windosr Gp.. suggests no relevant deformation events during this period.*

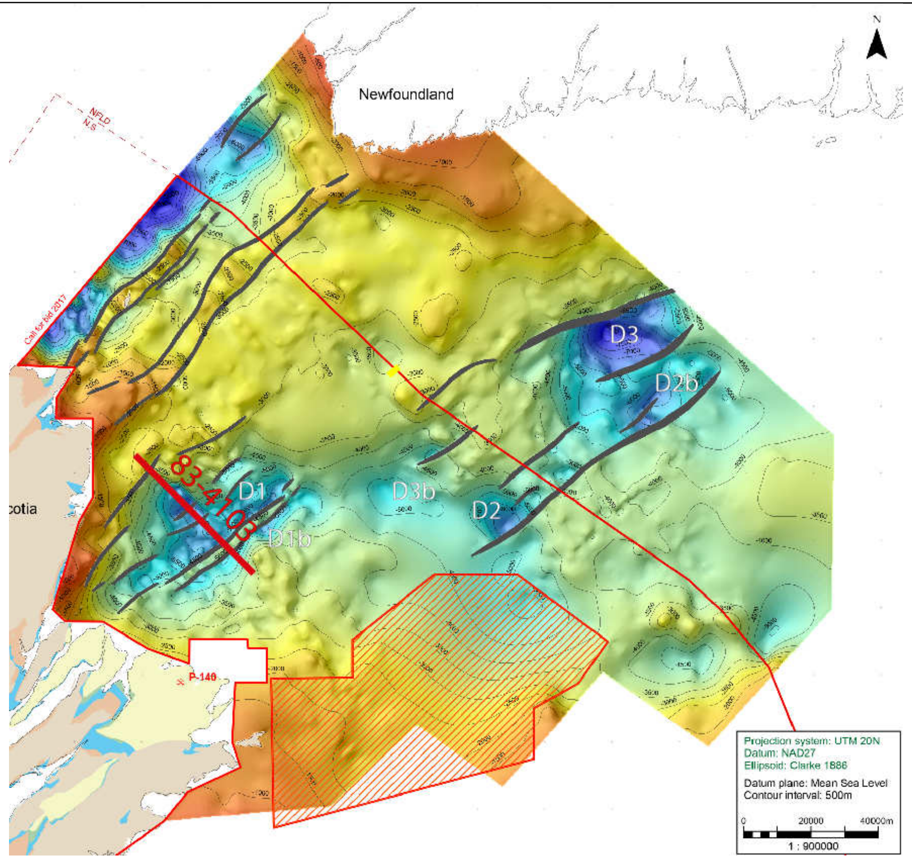
***Step-8**. The Lower Windsor Gp. shows a gradual thickening towards the right of the section (towards SE), due to subsidence. The normal fault highlighted in the section results active during this period.*



***Step-9**. This step shows the main transtensional deformation event affecting the Sydney Basin. It defined the main depocenters of the Early Carboniferous and controlled the deposition of the Horton Gp. The faults highlighted in red were active during this period.*



***Step-10**. All the normal faults active during the deposition of the Horton Gp. are restored. A lateral extension ~ 3.1 km has been calculated.*
The palaeo-relief of the pre-rift series is not sub-horizontal, and shows structural highs and depocenters. This would suggest a structurally complex "basement" affected by previous tectonic events (Pl. 2-4, 2-5)



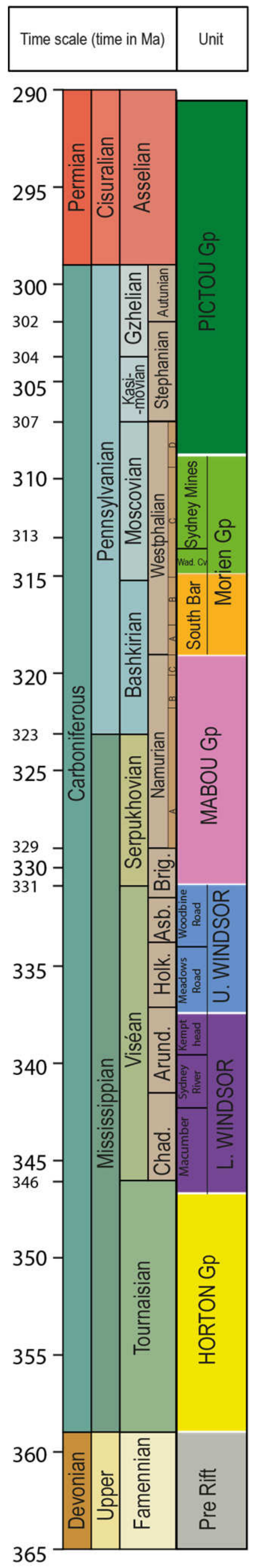


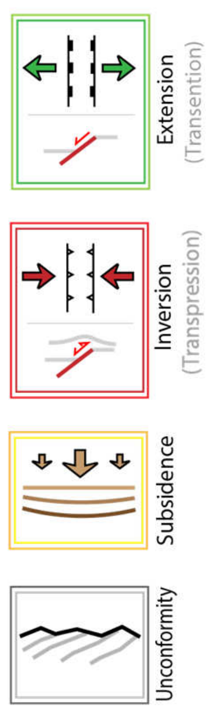
Figure 31 (Step-1–Step-10): Sequential Restoration of the seismic line 83-4103.

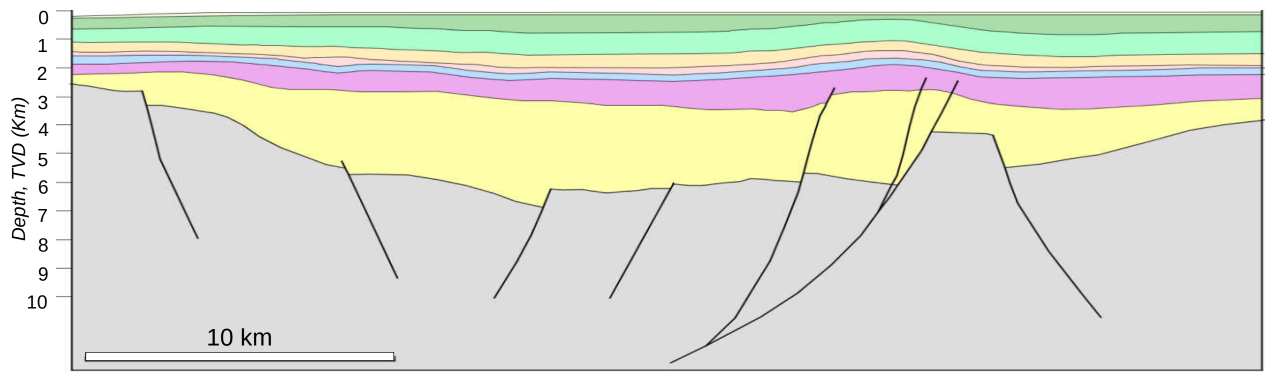
The sequential restoration illustrated below from the Present day (Step-0) to the Pre-Carboniferous (Step 9), shows the main tectonic events affecting the main depocenters of the Sydney Basin.
This area is characterized by a system of graben and semi-graben, opened under a transtensive regime during the deposition of the Horton Gp. (Middle Devonian/Lower Carboniferous).
The Horton Gp. thickness varies from 0.3 up to 3.5 km.

The North Sydney anticline is the result of an inversion of the North Sydney fault under a transpressive regime during the Lower Permian age (?).

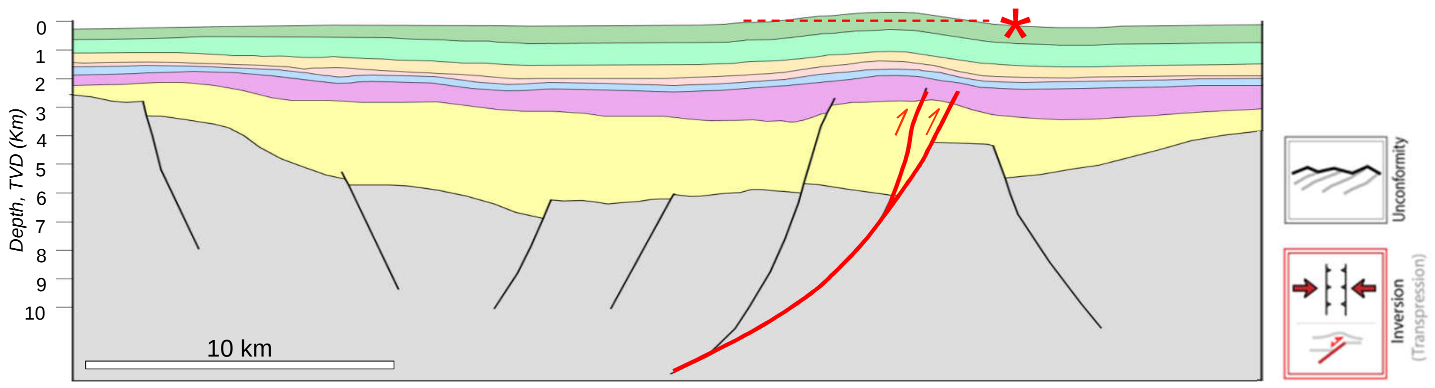
The back-stripped sections cannot be considered fully balanced because of the out-of-plane movements due to the lateral displacement component, in both transtensive and transpressive regimes.

Legend

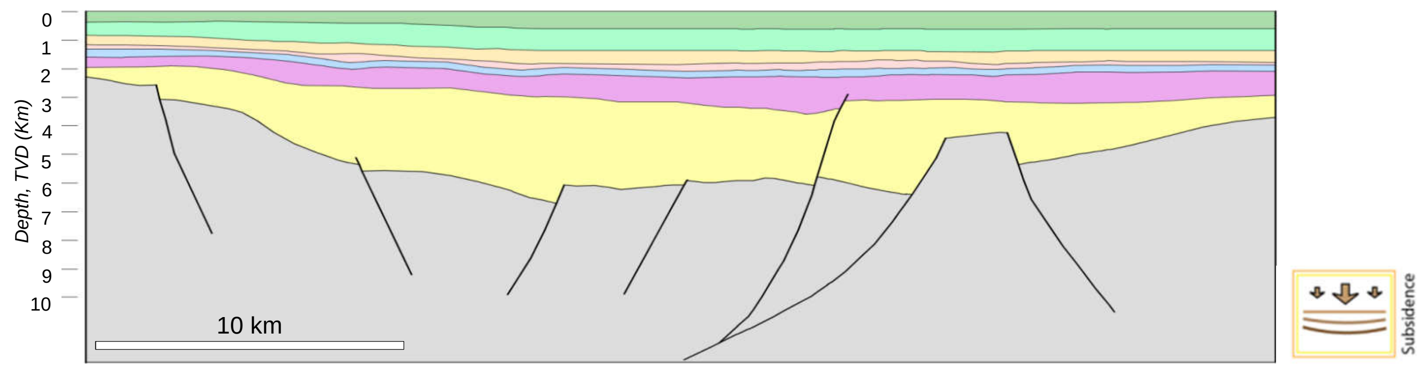




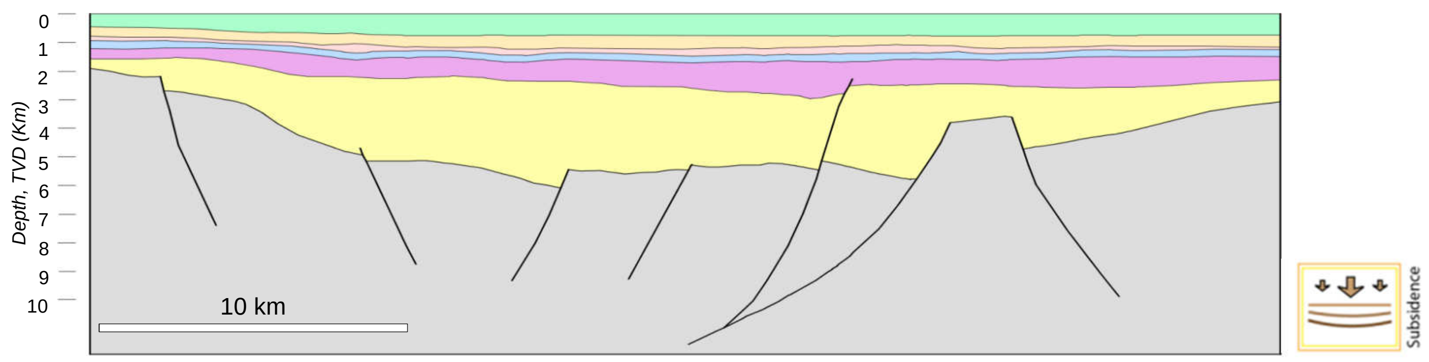
Step-1. Present day: few hundreds meters of recent sediments covers the Pictou Gp.



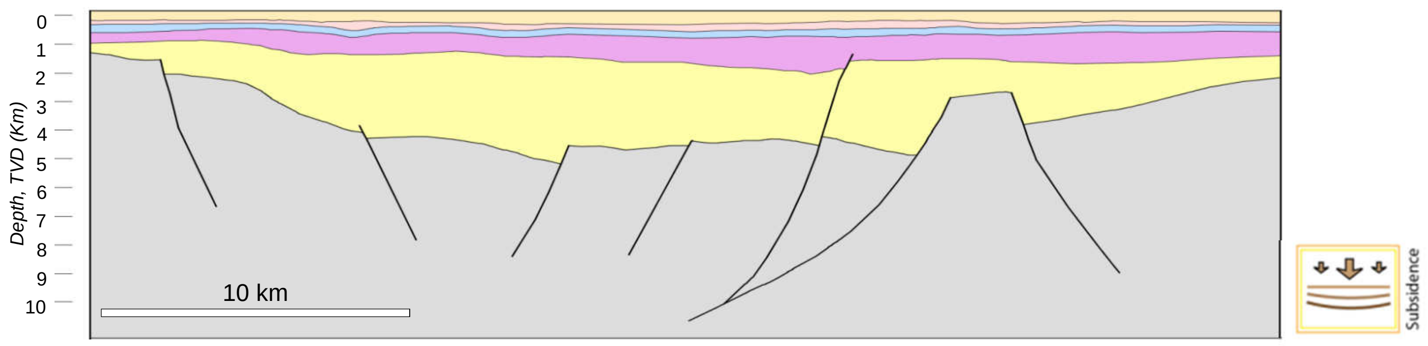
Step-2.The truncation (*) affecting the Pictou Gp was reconstructed,revealing up to 450 m of eroded sediments. The North Sydney anticline is related to the inversion of the North Sydney fault, active under a transpressive regime, during the Permian age (?)



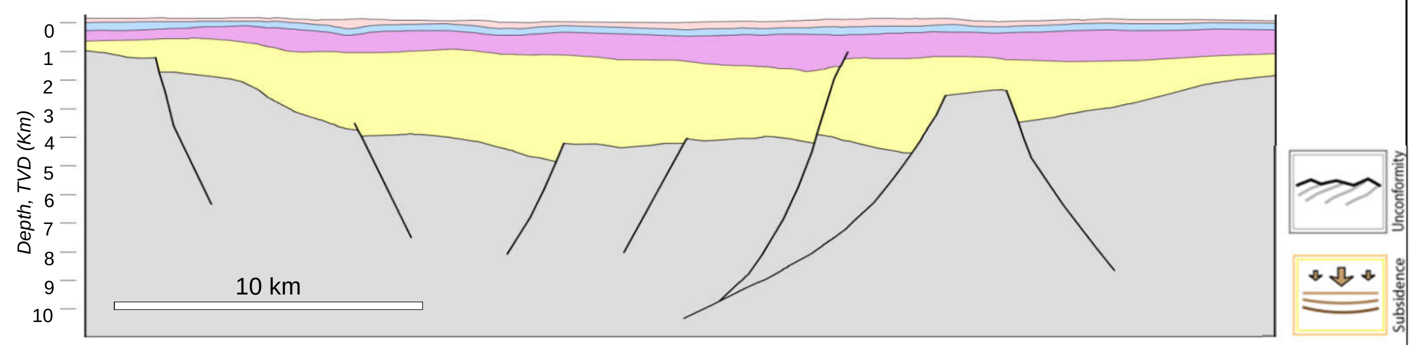
Step-3. The Permian (?) inversion (transpression) phase is restored. The North Sydney fault-related anticline is back-stripped. The constant thickness of the Pictou Gp. suggests no relevant deformation events controlling its deposition.



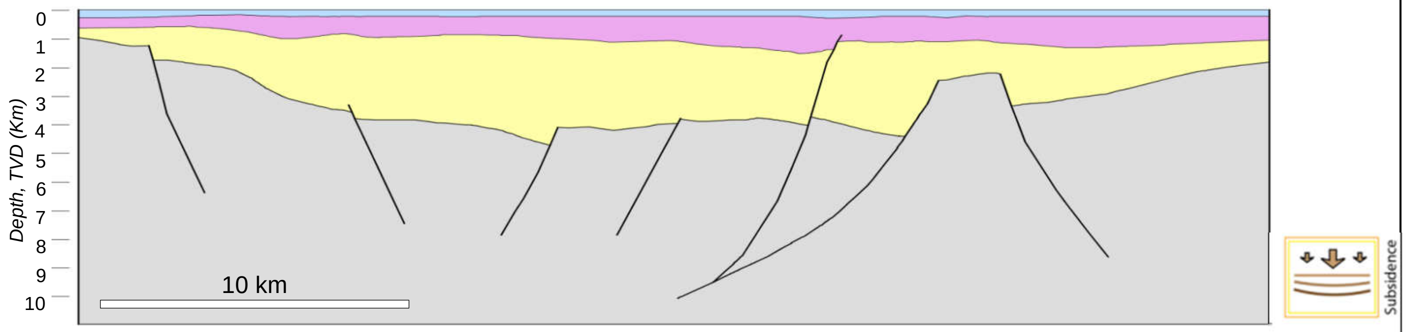
Step-4. The constant thickness of the Sydney Mine Fm suggests a regional subsidence and no relevant deformation events controlling its deposition.



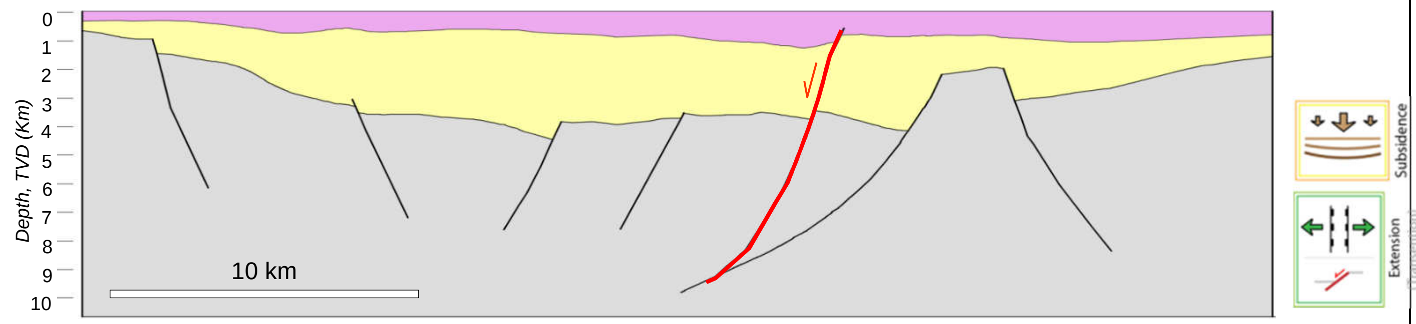
Step-5. The South-Bar Fm. shows no relevant thickness variation. This suggests a regional subsidence and no major deformation events during this period.



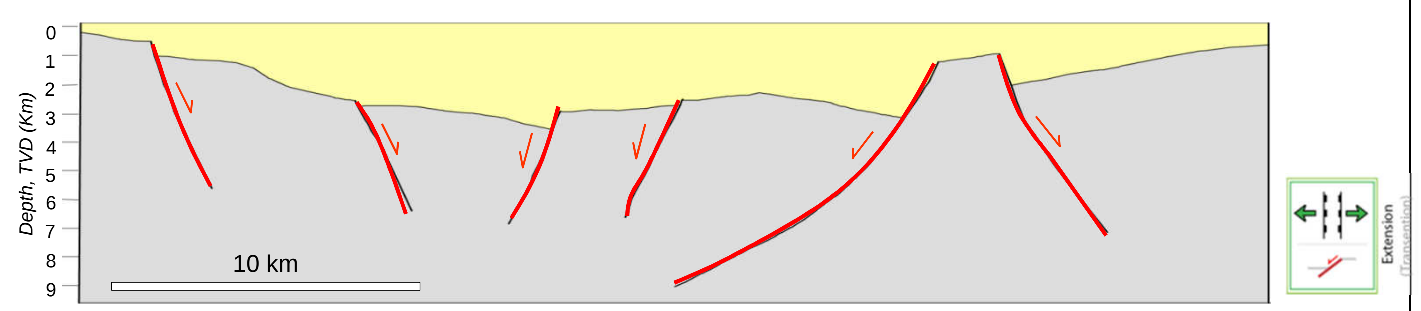
Step-6. The Mabou Gp deposited, as for the Pictou Gp. and Morien Gp. (South Bar Fm. and Sydney Mine Fm.) during a period tectonically quiet
The Top Mabout Gp. (Top Namurian) represents one of the major unconformity of the area, verified on both well and seismic data.



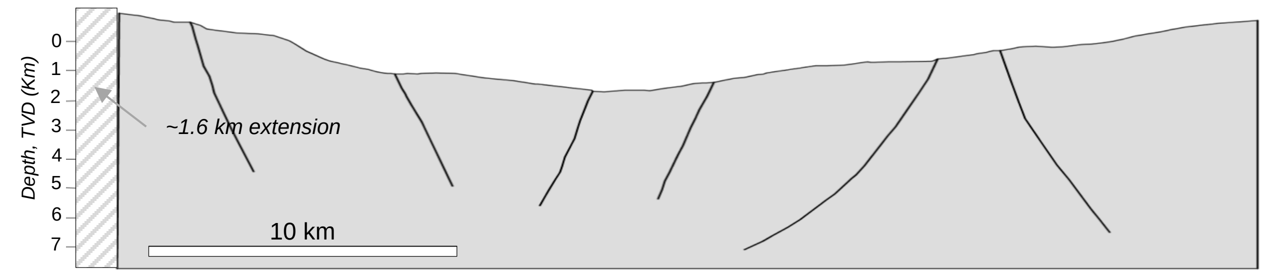
Step-7. The constant thickness of the Upper Windosr Gp. suggests no relevant deformation events during this period.



Step-8. The Lower Windsor Gp. shows relevant thickness variation both due to subsidence and fault activity. The normal fault highlighted in the section is active during this period.



Step-9. This step shows the main transtensional deformation event affecting the Sydney Basin. It defined the main depocenters of the Early Carboniferous and controlled the deposition of the Horton Gp. The faults highlighted in red were active during this period.



Step-10. All the normal faults active during the deposition of the Horton Gp. are restored. A lateral extension ~ 1.6 km has been calculated. The palaeo-relief of the pre-rift series is not sub-horizontal, but articulated with structural highs and depocenters. This would suggest a structurally complex ''basement'' affected by previous tectonic events (see slides 4-5-6).

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