Thrust systems in the eastern Amadeus Basin: Megathrusts and duplexes versus imbricate fans

Reuben Hansman[1,2], *Charles Verdel*[1] *and Nick White*[1]

Introduction

The structural and stratigraphic evolution of a sedimentary basin plays a fundamental role in mineral and energy systems. The timing and style of deformation directly control the maturation, distribution, preservation and connectivity of potential source rocks, reservoirs and seals in energy systems. For mineral explorers, structural models are crucial to understanding fluid flow pathways, heat flow and the development of traps or reactive host rocks favourable for mineral deposition. Developing evidence-based geological models underpins effective exploration targeting, resource assessment and risk-reduction strategies for both hydrocarbon and mineral resources.

The Northern Territory Geological Survey (NTGS) is currently remapping the Amadeus Basin to update the first edition 1:250 000 maps published in the 1960s. Major changes to the stratigraphy and structure have been identified, leading to the development of new structural models.

Geological setting

The Amadeus Basin is a major intracratonic sedimentary province in central Australia. It spans 850 km east–west, predominantly within the southern Northern Territory (**Figure 1a**) and extends into Western Australia. The basin contains a 14 km thick succession of Neoproterozoic (ca 850 Ma) to Carboniferous (ca 350 Ma) strata deposited in shallow-marine, fluvial and terrestrial environments. The basin's stratigraphy records a prolonged and complex geological history beginning in the Tonian with rift-related volcanics and siliciclastic rocks linked to the breakup of the Rodinia Supercontinent, followed by widespread carbonate, evaporite and siliciclastic deposition punctuated by major unconformities.

The structural architecture of the basin was strongly modified by two major orogenic events: the Ediacaran–Cambrian Petermann Orogeny (580–530 Ma) which propagated from south to north, locally uplifting and deforming the basin fill; and the Ordovician–Carboniferous Alice Springs Orogeny (450–300 Ma) which propagated from north to south and resulted in widespread deformation, basin inversion and foreland sedimentation. These tectonic episodes shaped the basin's present configuration.

Structural models

In the northeastern Amadeus Basin, previous mappers (Oaks *et al* 1991, Stewart *et al* 1991) proposed a megathrust and duplex model for this region (**Figure 1b**), which requires 60–70 km of horizontal shortening. Data were collected to test this model during ongoing fieldwork by NTGS mappers. Field evidence supporting the megathrust and duplex model is difficult to find. This is because Quaternary gravels cover the areas where thrusts should be in outcrop. Therefore, a new model is discussed, which invokes thrusts and imbricate fans, requiring only 10–15 km of horizontal shortening (**Figure 1c**).

Thrust systems: duplex versus imbricate fan

Duplexes and imbricate fans develop during horizontal shortening and can look similar in outcrop, depending on what has been eroded or preserved. Key distinguishing features for an antiformal duplex (**Figure 2a**) are the floor and roof thrusts, and a series of imbricated, fault-bound blocks (horses). During deformation, as new horses form in the footwall, the older horses are rotated, and bedding is steepened towards the hinterland. Additionally, the ramp faults curve away from the floor thrust and curve back into the roof thrust.

An imbricate fan is differentiated from a duplex by the lack of a roof thrust (**Figure 2b**). The imbricate faults are listric (ie they curve away from the detachment and become steeper with distance from the fault), rather than curving back toward a roof thrust, as is the case in a duplex. Anticlines and synclines can form in both thrust systems, but the fault geometries are distinct. In map view, duplex ramps appear curved (with the bedding; **Figure 2a**); whereas, an imbricate fan system has sub-parallel faults that cut through the folded stratigraphy (**Figure 2b**). These differences are necessary for testing the megathrust and duplex model and evaluating the proposed imbricate fan model.

Megathrust and duplex model

Previous mappers proposed a megathrust model in the northeastern Amadeus Basin, (Oaks *et al* 1991, Stewart *et al* 1991), in which a nappe moved 60–70 km southward along a detachment during the Alice Springs Orogeny. Evidence for this model is sparse, as the proposed nappe is mostly above the present-day topography, and is eroded away. Structures interpreted to belong to this system only outcrop in the north and south, so a complete structural profile is not exposed.

The MOVE structural geology software suite (Petroleum Experts Ltd 2025) was used to create a forward model (**Figure 1b**), that replicates the balanced cross-section from Oaks *et al* (1991). This model is simplified but replicates the main structures over four stages:

1. Deposition: layer-cake deposition of the Tonian to Cambrian sedimentary rocks.
2. Megathrust sheet emplacement: initiation of the Alice Springs Orogeny which causes horizontal shortening in the north and forms a detachment within the weak salt layer of the Gillen Formation (Bitter Springs Group). The detachment ramps up and flattens in the salt layer of

---

[1] Northern Territory Geological Survey, GPO Box 4550, Darwin NT 0801, Australia

[2] Email: reuben.hansman@nt.gov.au

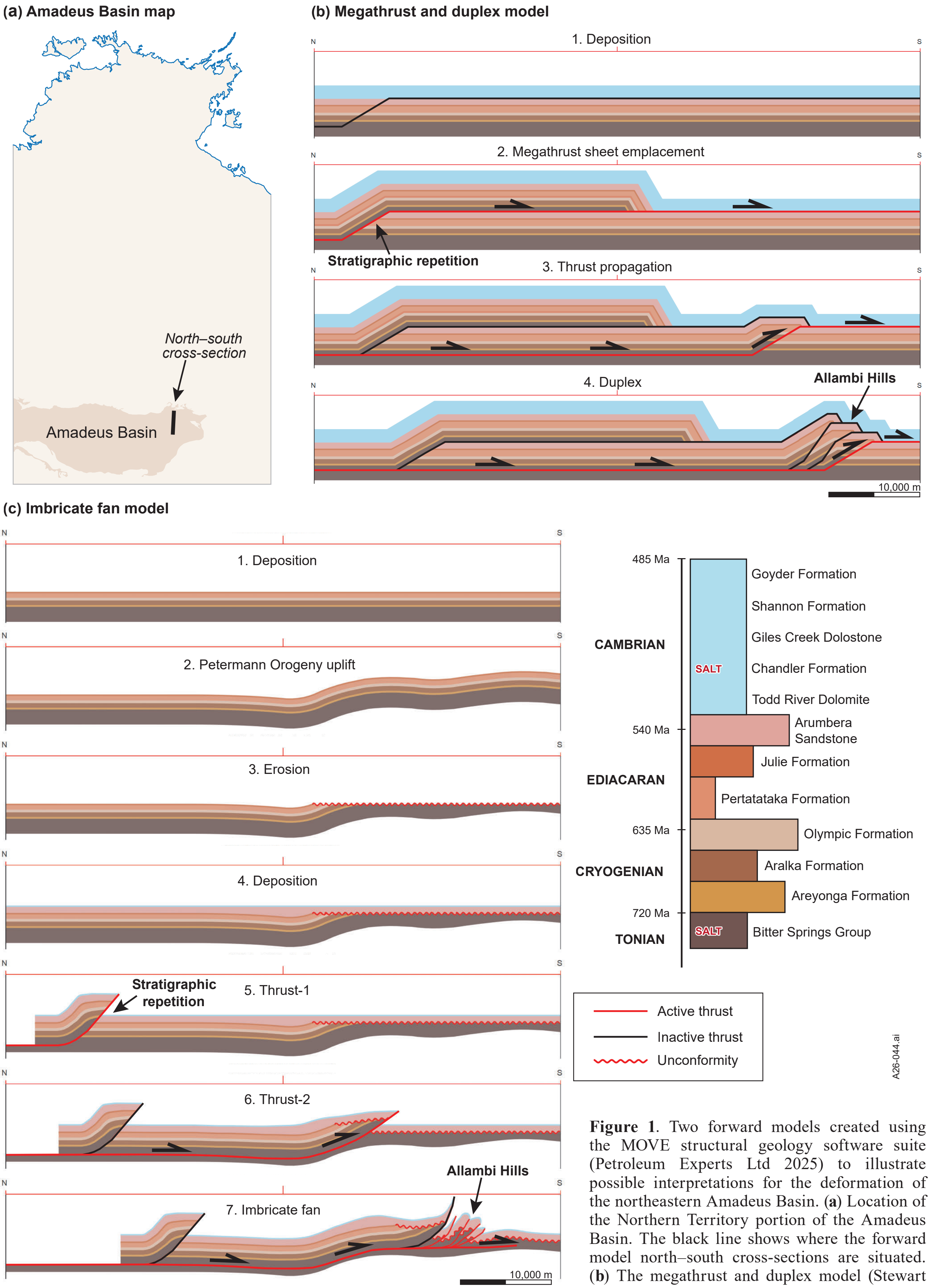

Figure 1. Two forward models created using the MOVE structural geology software suite (Petroleum Experts Ltd 2025) to illustrate possible interpretations for the deformation of the northeastern Amadeus Basin. (**a**) Location of the Northern Territory portion of the Amadeus Basin. The black line shows where the forward model north–south cross-sections are situated. (**b**) The megathrust and duplex model (Stewart *et al* 1991), requiring ~70 km of horizontal displacement (model shortened to 30 km to fit the page). (**c**) Alternative imbricate fan model, requiring only ~10 km of horizontal shortening.

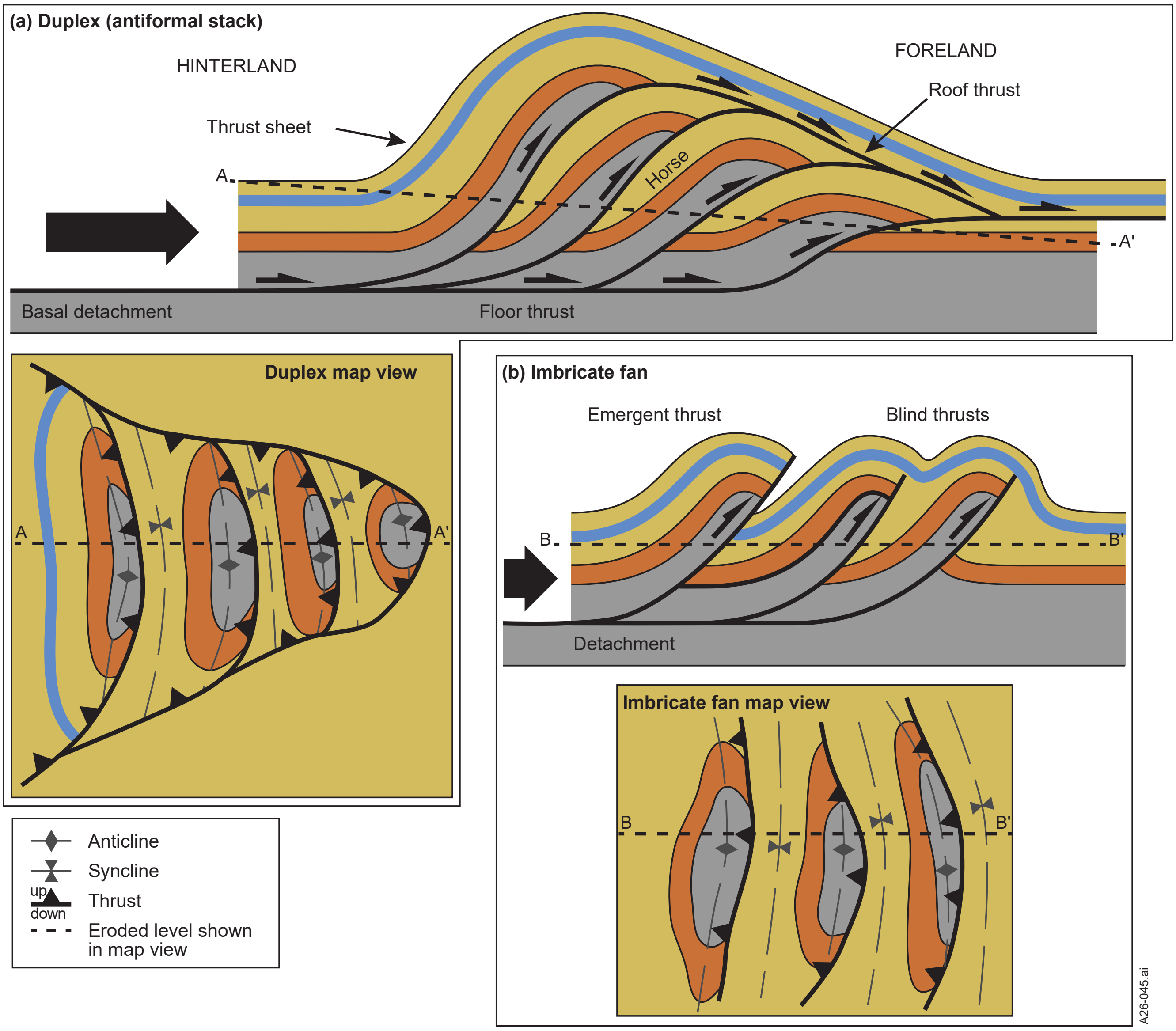

Figure 2. Schematic diagrams of two end-member thrust system geometries. (**a**) A leading imbricate fan, characterised by forward-propagating imbricate listric thrusts. (**b**) A hinterland-dipping duplex showing stacked thrust slices bounded by a roof thrust and a floor thrust.

the Chandler Formation. Displacement along the ramp causes stratigraphic repetition of the formations seen in outcrop in the north of the basin.

3. Thrust propagation: a new ramp forms southward in the footwall as the detachment propagates south.
4. Duplex: a series of ramps develop, forming a duplex thrust system (Allambi Hills).

A fault-bend-fold algorithm in MOVE was used to model the faults and is based on the work of Suppe (1983). This section is line-length and area balanced between undeformed and deformed states.

Imbricate fan model

NTGS mappers carried out fieldwork in the northeastern Amadeus Basin during 2023–2025. The new field data support an imbricate fan model (**Figure 1c**), rather than the megathrust (with duplex) model described above. The major findings were:

1. Bedding on the northern margin of each thrust block (horse) dips 40–50° north. This geometry is consistent with an imbricate fan system (**Figure 2b**); whereas, a duplex (**Figure 2a**) predicts progressive steepening of dip towards the hinterland (northward).
2. No evidence was found for faults curving in map view, as required by the duplex model (**Figure 2a**). The majority of faults mapped in the megathrust model are inferred to be concealed beneath Quaternary gravels (Oaks *et al* 1991).

In addition, an unconformity between the Arumbera Sandstone and the Bitter Springs Group was identified in the south. Although this does not affect the validity of either model, it was incorporated into the imbricate fan model to reflect the field data.

A model integrating imbricate thrusts explains the surface geology without invoking a megathrust sheet that has subsequently been eroded. MOVE was used to create a forward model (**Figure 1c**) over seven stages:

1. Deposition: layer-cake deposition of the Tonian to Ediacaran stratigraphy.
2. Petermann Orogeny uplift: uplift in the south due to the Petermann Orogeny
3. Erosion.
4. Deposition: continued deposition through the Cambrian.
5. Thrust-1: initiation of the Alice Springs Orogeny, with deformation along a detachment within the Gillen Formation salt layer (Bitter Springs Group) propagating upward as a south-directed thrust fault, causing stratigraphic repetition.
6. Thrust-2: initiation of a second thrust in the footwall as deformation continues.
7. Imbricate fan: development of a series of listric thrusts propagating into the foreland, creating an imbricate fan system (Allambi Hills).

This model requires a total of 12.5 km of horizontal shortening. The fault parallel flow (Egan *et al* 1997) in MOVE was used to model thrusts 1,2 and 3, and a trishear algorithm (Erslev 1991) was used to model the imbricate fan. This model is kinematically admissible and geometrically consistent between undeformed and deformed states.

Conclusion

Both models discussed here explain the stratigraphic repetition in the north and the series of thrusts and folds in the south (Allambi Hills) of the northeastern Amadeus Basin. However, the megathrust model predicts ~70 km of horizontal shortening; whereas, the imbricate fan model predicts ~10 km.

A critical distinction between the models lies in the interpretation of thrust geometries in map view (curved versus sub-parallel), particularly where structures are concealed beneath Quaternary gravels. Although geological maps may accurately depict lithological distributions in outcrop, structural interpretations are inherently uncertain where faults are not directly exposed. Consequently, mapped structural geometries in such areas are strongly interpretative and should be critically evaluated before being used to support structural models or guide exploration decisions.

References

Egan SS, Buddin TS, Kane SJ and Williams GD, 1997. Three-dimensional modelling and visualization in structural geology: New techniques for the restoration and balancing of volumes: in *‘Proceedings of the 1996 Geoscience Information Group Conference on Geological Visualisation’. Electronic Geology* 1, Paper 7, 67–82.

Erslev EA, 1991. Trishear fault-propagation folding. *Geology* 19, 617–620.

Oaks RQ, Stewart AJ, Deckelman JA and Conrad KT, 1991. *Geology of the northeastern Amadeus Basin, NT. 1:100 000 scale.* Bureau of Mineral Resources, Australia.

Petroleum Experts Ltd, 2025. MOVE (version 2024.1) structural geology software. Available from https://www.petex.com/products/move-suite/

Stewart AJ, Oaks RQ, Deckelman JA and Shaw RD, 1991. ‘Mesothrust’ versus ‘megathrust’ interpretations of the structure of the northeastern Amadeus Basin, central Australia: in Korsch RJ and Kennard JM (editors). *‘Geological and geophysical studies in the Amadeus Basin, central Australia’. Bureau of Mineral Resources, Australia, Bulletin* 236, 361–383.

Suppe J, 1983. Geometry and kinematics of fault-bend folding. *American Journal of Science* 283, 684–721.