Fault-controlled deltaic systems along-strike depositional variability (Crati Basin, eastern margin)

Candela Martinez, PhD in Department of Earth Science Royal Holloway University of London

Introduction

Deltaic systems can be classified into: (i) base-of-scarp, (ii) Gilbert-, and (iii) shelf-type based on the depth of water in the receiving basin, the sediment supply, and the gradient of the depositional slope, which in turn control the stratal architecture and facies type distribution within each delta type. When these types of deltas develop in tectonically active settings, related to faulted margins, their stratigraphic architecture is also controlled by temporal and spatial variability in fault slip rate and relative sea-level changes.

This study aims to address the along-strike architectural variability of Pliocene-Pleistocene deltaic systems deposited in the eastern margin of the Crati Basin (southern Italy; Figure 1), which is characterised by an array of major N-S striking normal faults (Figure 1), and a secondary fault network composed of NE-SW and NW-SE-striking faults, developed since the Pliocene-Early Pleistocene. To assess these deposits architectural variability, we had the following objectives: (i) construct strike and dip logs along the basin margin to determine facies and sourcing areas, (ii) establish outcrop-based internal geometry and architectural variability, and (iii) build correlation panels to assess lateral geometry and facies changes. To achieve so, we divided the eastern margin into three sectors (i.e., southern, central, and northern; Figure 2), with fault throw greatest in the northern sector and decreasing southwards. A total of thirty-nine outcrops location were studied, thirteen located in the southern area, fourteen in the central area, and twelve in the northern area (Figure 2).

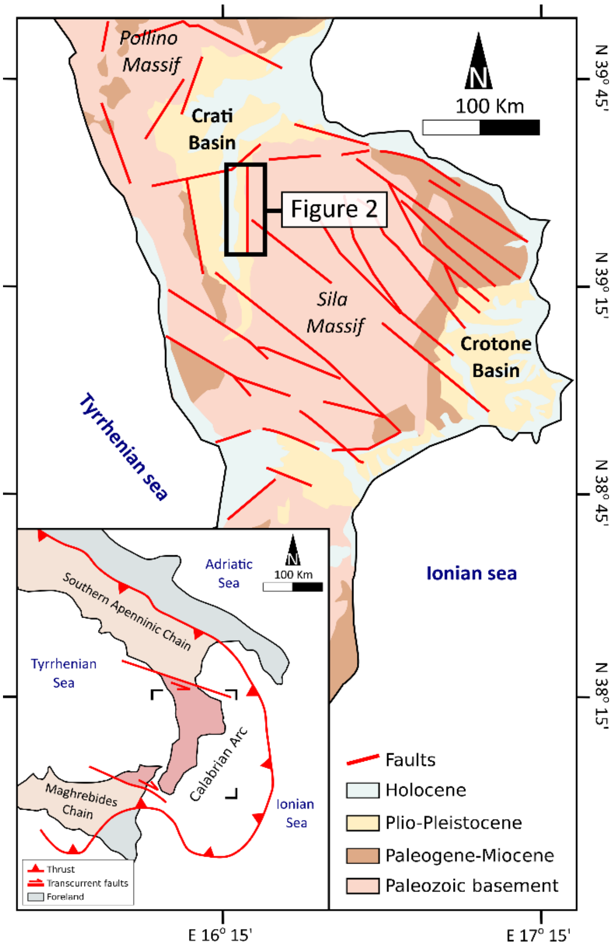


Figure 1: Simplified geological map of the Calabrian Arc (modified after Chiarella et al., 2021). Main fault systems, and ages of the rocks are displayed. The black square represents the extension of the study area. Italy mayor structural elements (bottom left insert), including thrust related to the subduction of the Ionia Sea, and mayor strike-slip faults that controlled the migration towards the SE of the Calabrian Arc.

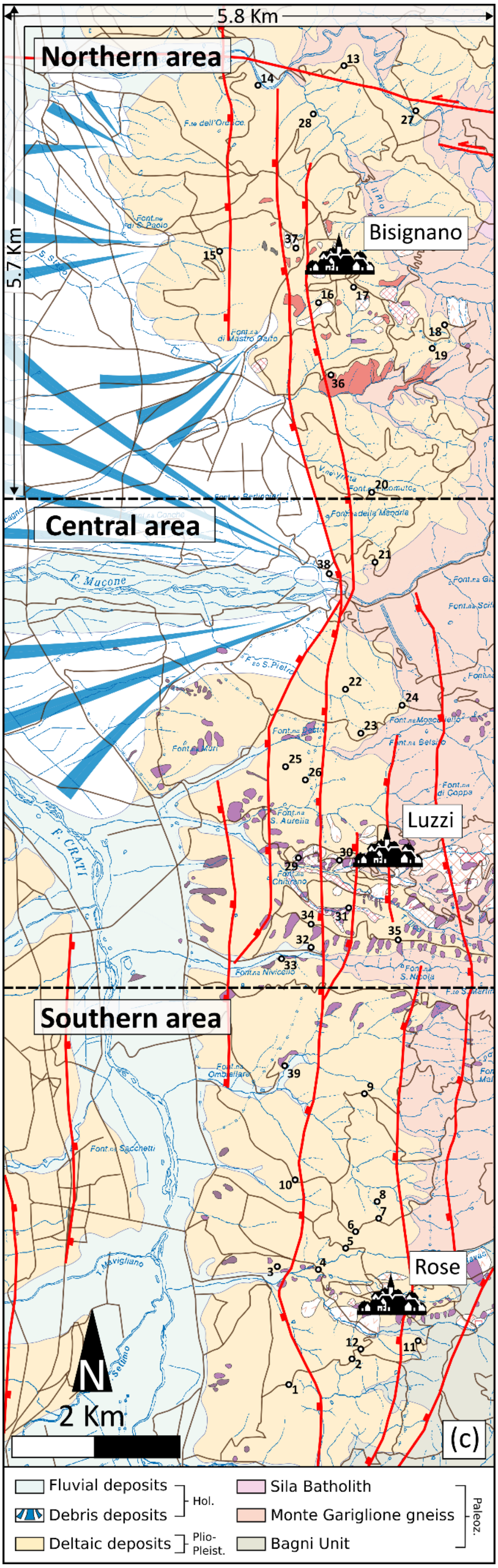


Figure 2: Geological map of the study area, modified after Tansi et al., (2016) (location shown in Figure 1), with the division used in this study displayed (northern, central, and southern areas which are 5.7 X 5.8 km). Main faults are displayed, serving as eastern margin of the Crati Basin (array of N-S striking normal fault, dipping to the west). Locations (L1 – L39) used to conduct this study are displayed (black circles).

Field work and data analysis

Facies description (Appendix 1, Table 1), large-scale architectures (Figure 3-5a, b), and log correlation (Figures 3-5c) indicated that sediment was mainly sourced from the uplifted eastern basin margin where the basement outcrops, with the footwall-derived bodies prograding towards the depozone in the west. Sediments were eroded from the uplifted footwall areas, and deposited in the hangingwall, with their bioclastic content indicating relatively shallow marine conditions.

To properly address the Plio-Pleistocene deposits architectural along- and across-strike variability in the subside hangingwall of the eastern margin of the Crati Basin, we considered the studied outcrops lithology and architecture, spatial location (i.e., GCS), altitude (i.e., meters above sea level-m. a. s. l).

Log correlation shows dominance of coarse-grained material (i.e., conglomerates) near the faulted margin, thinning and fining westwards into fine-grained sandstone to siltstone (Figure 3-5c). Preliminary results indicate that in the early phase shelf-type deltas (Figure 3-5c) developed above the basement along the entire length of the subsided hangingwall. Deposits related to these shelf-type deltas are characterised by the dominance of Sub-facies F1 (Appendix 1, Table 1), resulting in sub-horizontal beds (Figure 3-5a).

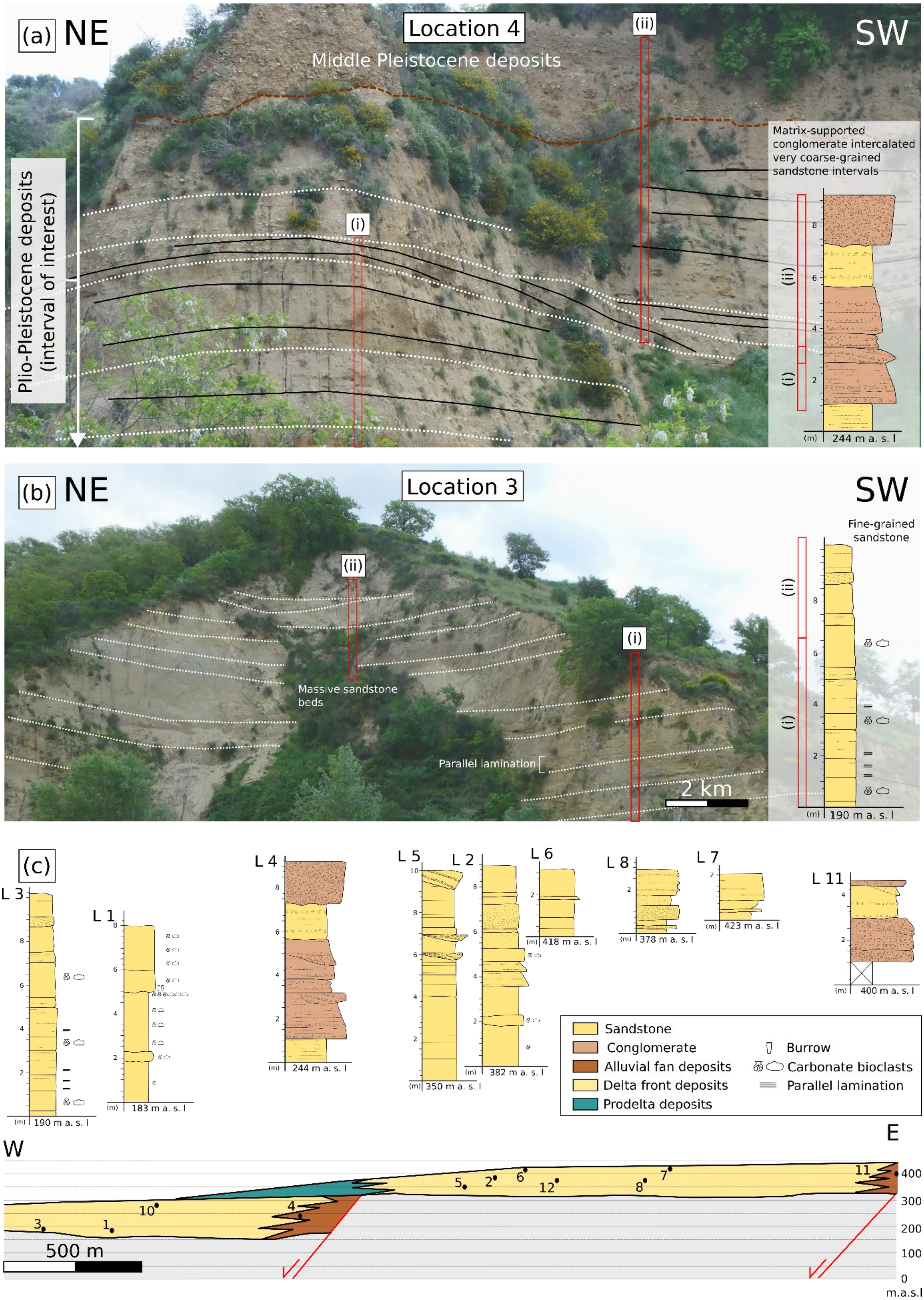


Figure 3: (a,b) Shelf-type delta deposits, dominance of Sub-facies F1 organised in sub-horizontal tabular beds, which are intercalated with deposits of Facies D and E (a and b, respectively). (c) Southern area sedimentary logs and logs correlation, displaying the deposition of two vertically stacked shelf-type deltaic systems.

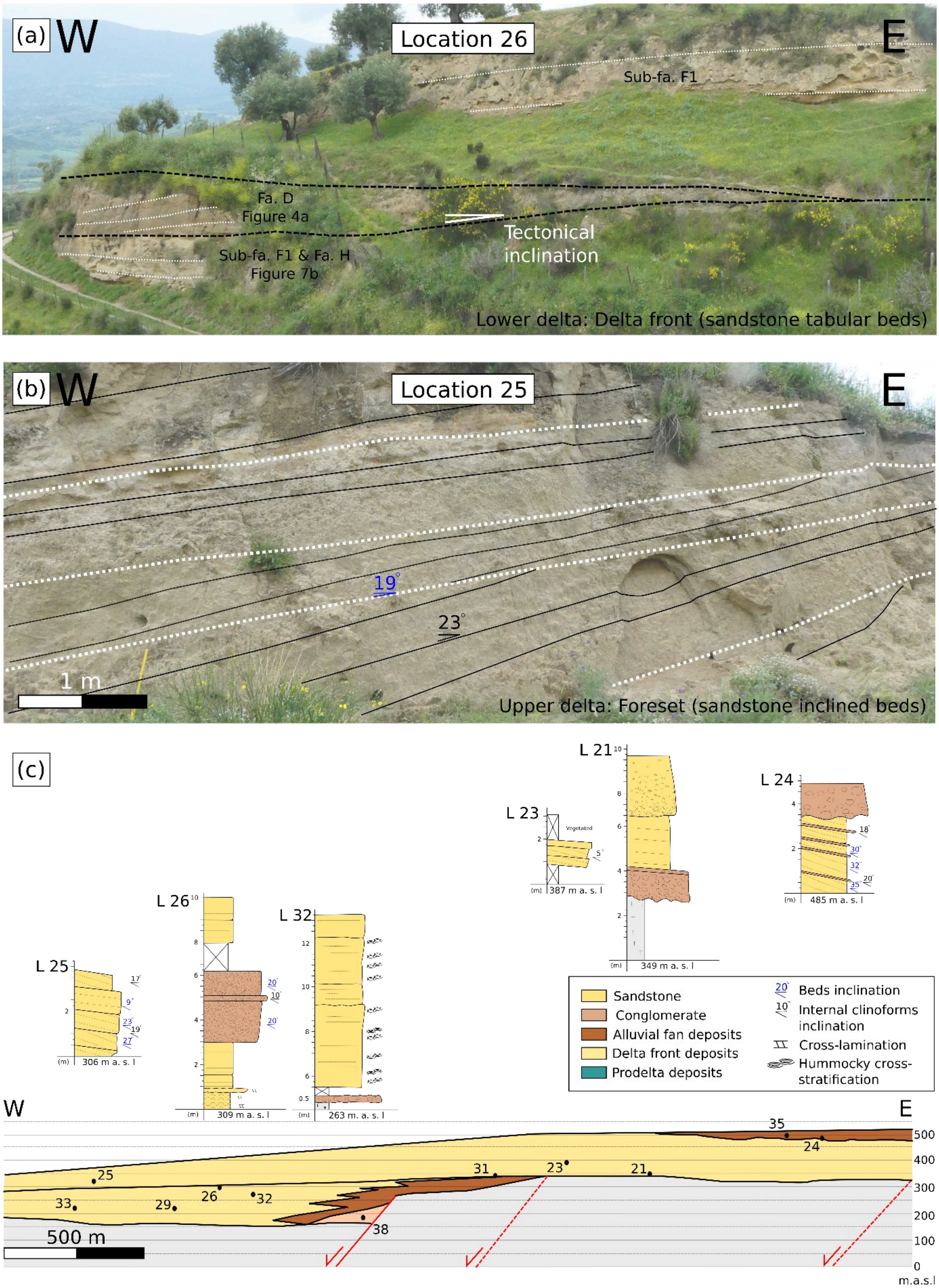


Figure 4: (a) Shelf-type delta deposits, dominance of Sub-facies F1 organised in sub-horizontal tabular beds, which are intercalated with deposits of Facies C, D, and E. (b) Gilbert-type delta deposits, characterised by the accumulation of deposits of Sub-facies F2 organised in inclined or cross-stratified tabular beds. (c) Central area sedimentary logs and logs correlation, displaying the deposition of two vertically stacked deltaic systems. A lower shelf-type delta overlaid by a Gilbert type delta.

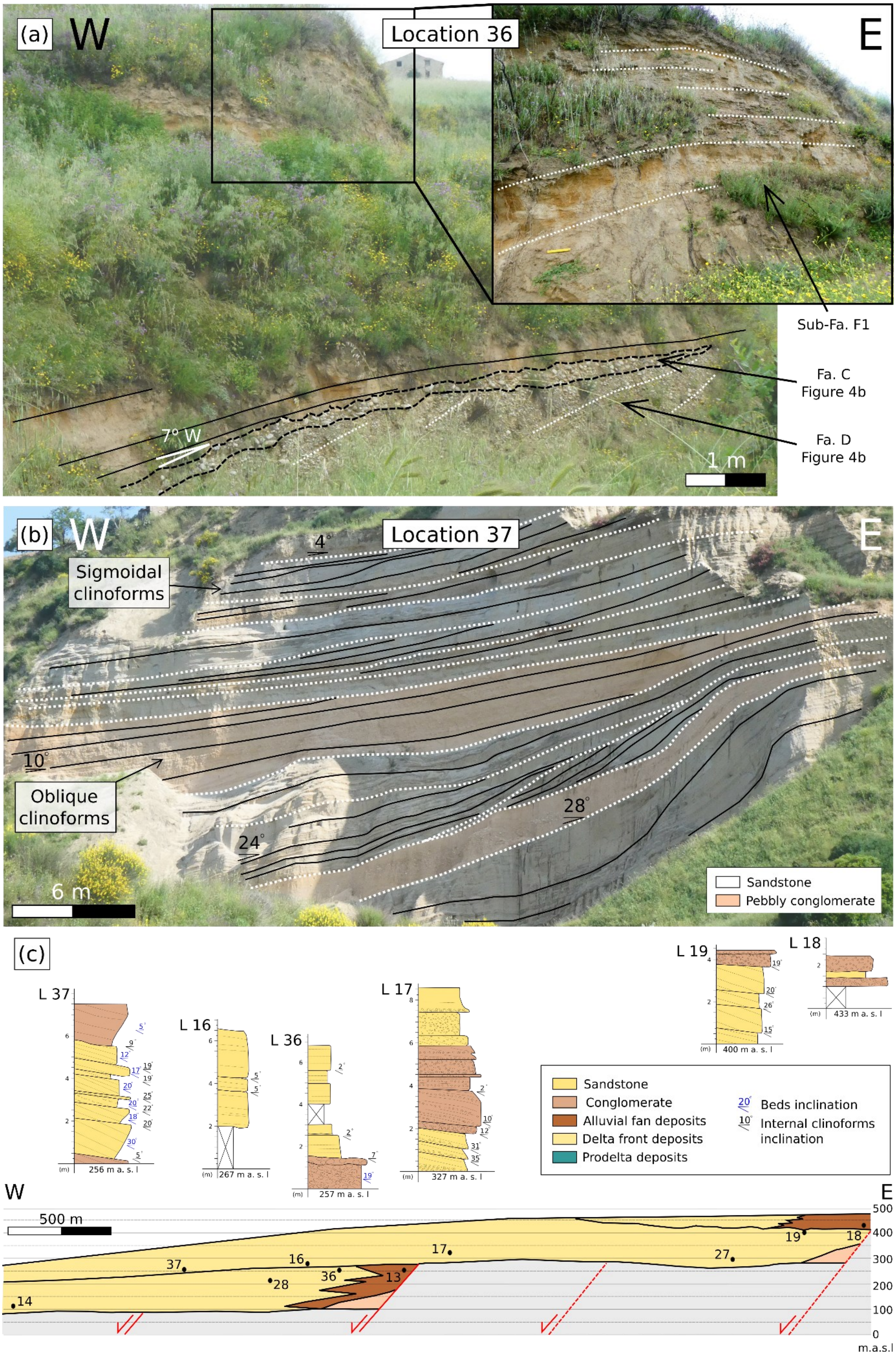


Figure 5: (a) Shelf-type delta deposits, dominance of Sub-facies F1 organised in sub-horizontal tabular beds, which are

intercalated with deposits of Facies C, and D. (b) Gilbert-type delta deposits, characterised by the accumulation of deposits of Sub-facies F2 organised in inclined or cross-stratified tabular beds. (c) Northern area sedimentary logs and logs correlation, displaying the deposition of two vertically stacked deltaic systems. A lower shelf-type delta overlaid by a Gilbert type delta.

Stratigraphically above, the northern and central sectors are characterised by the deposition of Gilbert-type deltas (Figure 4-5c). Deposits used to identify Gilbert-type deltas pertain to Sub-facies F2 (Appendix 1, Table 1), being organised into inclined or cross-stratified beds (Figure 4-5b). However, coeval with the deposition of Gilbert-type deltas, along the southern area, shelf-type deltas continued to develop (Figure 3c).

Preliminary results

Our results suggest that the growth of the Crati Basin eastern margin was characterised by initial low gradient depositional slopes and the formation of shelf-type deltas. Continued syn-sedimentary growth of the margin resulted in steeper depositional slopes along the central and northern sectors and the related development of Gilbert-type deltas.

Appendix 1

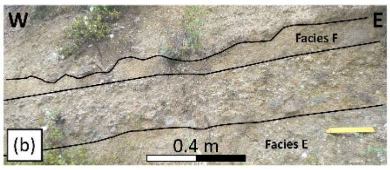
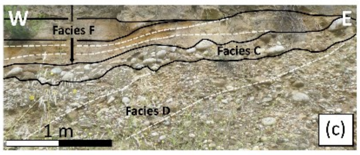
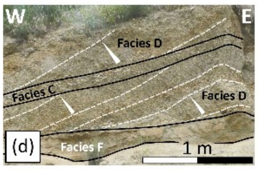
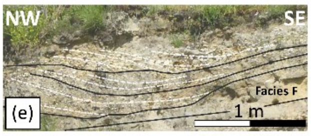
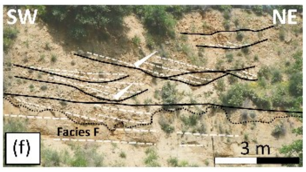
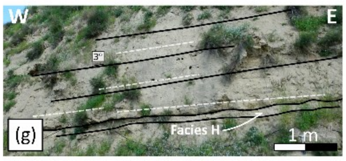
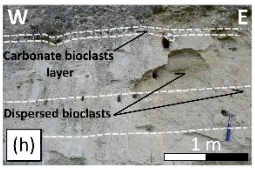
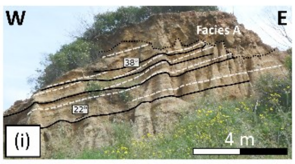
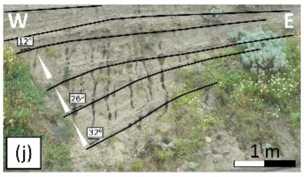
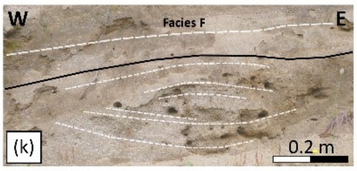
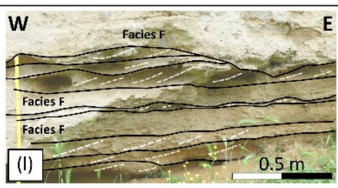
		Facies description
Facies A		**Description** - Massive clast-supported conglomerate - Pebble to boulder clasts (60 to 900 mm), sub-angular to rounded, and poorly sorted. Clast c-axis generally oriented E-W - Massive beds (> 1 m thick) **Interpretation** - Rapid highly concentrated, cohesionaless debris flow
Facies B		**Description** - Crude clast-supported conglomerate - Pebble to cobble clasts (4 to 70 mm), angular, poorly sorted - Tabular beds (<0.2 m thick) **Interpretation** - Laminar flow related to a non-cohesive debris flow
Facies C		Description - Clast-supported conglomerate - Cobble to boulder clasts (70 to 300 mm), roderately, and moderatly sorted. Clasts c-axis oriented E-W - Thin continuous layers, generally overlying Fa. D (<0.2 m thick) Interpretation - Rapid flow related to a non-cohesive debris flow
Facies D		**Description** - Normal-graded clast-supported conglomerate - Pebble to cobble clasts (5 to 140 mm), sub-rounded, moderately sorted. Clasts c-axis oriented E-W - Bodies pinch-out laterally (>1 m thick) with inclined or cross-stratified beds (12 to 50 cm thick), capped by Fa. C **Interpretation** - Non-cohesive turbulent flow, related to tractional transportation and the migration of conglomeratic mouth-bar deposits
Facies E	 	**Description** - Normal graded matrix- and clast-supported conglomerate - Pebble to cobble clasts (40 to 700 mm), sub-rounded, moderatly sorted - Vertically stacked lenticular bodies (> 1m thick), characterised by through-cross bedding (10 to 60 cm thick) **Interpretation** - Turbulent non-cohesive flows, transported through traction along channelised paths, and representing channel fill-deposits
Facies F — F1	 	**Description** - Structureless or normal-graded fine- to coarse-grained sandstone, grains sub-angular and moderately sorted. Dispersed or scattered into apparently non-continuous thin layers pebble size clasts and/or carbonate bioclasts - Tabular beds up to 2 m thick - Passing basinwards to finer sediments **Interpretation** - Tractional, rapid, highly concentrate sandy flow, transported through a low gradient depositional slope
Facies F — F2	 	**Description** - Structureless or normal-graded medium to very coarse-grained sandstone or pebbly conglomerate (max 60 mm) - Inclined beds (12-35°) up to 1.5 m thick and characterised by sigmoidal to oblique stratification Interpretation - Tractional, rapid, highly concentrate sandy flow, transported through a low gradient depositional slope
Facies G		**Description** - Very coarse-grained sandstone - Hummocky cross-stratification - Beds thickness varies from 2 m to 20 cm interbedded with Fa. F **Interpretation** - Depostion related to storm events, related to a unidirectional and oscillatory flows
Facies H		**Description** - Coarse-grained sandstone to gravel (0.7 to 3mm) - Cross-lamination - Organised in continuous <15 cm thick layers. **Interpretation** - Deposition related to an unidirectional flow, leading to tractional trasportation of sand grains and resulting in the migration of subaqueous dune

Table 1: Facies description. **(a)** Facies A: Massive clast-supported conglomerate composed of pebble to boulder clast (c. 60 to 900 mm), which their c-axis is generally oriented E-W. These clasts are mainly shades of beige, although naturally grey, sub-rounded to rounded, and poorly sorted and crystalline-metamorphic in nature. Beds are up to 1 m thick and generally

characterised by erosive bases. **(b)** Facies B: Crude clast-supported conglomerate beds composed of pebble to cobble (c. 4 to 70 mm). These clasts are naturally dark and grey, angular to sub-angular, and poorly sorted, and crystalline-metamorphic in nature. Beds are tabular up to 20 cm thick, slightly inclined basinward approximately 2°- 4°. **(c)** Facies C: Thin, continuous layers clast-supported conglomerate composed of cobble to boulder clast (c. 70 to 300 mm), rounded, and moderately sorted. Clast are inclined and oriented E-W, and grey shades. **(d)** Facies D: Inclined or cross-stratified, normal-graded, clast-supported conglomerate composed of pebble to cobble (5 to 140 mm). These clasts are shades of grey, beige, and dark brown colours, shaped sub-rounded, and moderately sorted, which their c-axis is generally oriented E-W. This facies is organised into bodies that pinch out laterally, with a flat base and concave top, and an overall minimum thickness of 1 m. The beds thickness ranges from 12 to 50 cm, being inclined towards the west. This facies is frequently capped by Facies C. **(e, f)** Facies E: Normal-graded matrix- and clast-supported conglomerate composed of pebble to boulder (40 to 700 mm). These clasts are grey and beige shades of crystalline-metamorphic nature, which are mostly inclined and oriented E-W, being flat and sub-rounded, and moderately sorted. The matrix, if present, is composed of coarse-grained sands. This facies is organised into vertically stacked lenticular bodies (1 to 7 m wide) with a convex base. These lenticular bodies present a maximum thickness of 1 m and are characterised by through cross-bedding. The beds thickness ranges from 10 to 60 cm thick. **(g, h)** Sub-facies F1: Sub-facies F1 is organised into beds (0.30 – 2 m thick), gently inclined 2-3° westwards. This sub-facies is composed of fine- to very coarse-grained sands, characterised by sub-angular and moderately sorted grains. Deposits of this facies are dominant along the studied outcrops in the southern area, where a passing basinward to siltstone trend is observed. Moreover, dispersed pebble size clasts and/or carbonate bioclasts, which in some cases are scattered into apparently non-continuous thin layers (up to 5 cm), are present within the very coarse- to medium-grained sand. **(i, j)** Sub-facies F2: Sub-facies F2 is organised into tabular (0.30 – 1.30 m thick) inclined (12-35°) westwards beds, which are composed of medium to coarse-grained sands and pebbly conglomeratic (maximum size c. 60 mm), moderately sorted. These beds are characterised by sigmoidal (i.e., ~ 1m thick thinning to 0.15 m towards the faulted margin) or oblique stratification (<1.30 m thick), leading to an upwards decrease in stratigraphic dip up to become sub-horizontal. **(k)** Facies G: Continuous layers characterised by hummocky-cross stratification, composed of very coarse-grained sandstone, with dispersed pebble size clasts (c. 4 to 24 mm). The grains are sub-rounded and moderately sorted. Beds thickness varies from 0.2 to 2 m, being interbedded with Sub-facies F1. **(l)** Facies H: Coarse-grained sandstones to gravel (0.7 to 3 mm), grains are sub-rounded, and moderately sorted. Deposits of this facies are organised in continuous thin beds, up to 0.15 cm thick, with an asymmetrical wavy top, and internally characterised by cross lamination.