Table S1. Summary of lithology, lithofacies, sedimentary structures, and depositional environments of the Lower Anti-Atlas Supergroup (LAAS) lithostratigraphic units in the Igherm Inlier. Siliciclastic facies codes and terminology follow [114,115,207], whereas carbonate facies classification follows [131,208–211].

Lithostratigraphic Unit	Facies Code	Lithofacies Description	Diagnostic Sedimentary Structures	Facies Association	Depositional Process	Interpreted Environment
Coarse-Grained *Quartz Sandstone Unit (Tasserda Fm)*	**Sp (compound sets)**	Compound cross-stratified coarse- to very coarse-grained sandstones; clasts up to 15 cm, subrounded to rounded; superimposed sets with erosional bases	Compound planar cross-stratification; superimposed sets; variable foreset dip angles; erosional set boundaries	FA1 – Sandy bedload channel	Migration of superimposed 2-D dune bedforms under sustained high-energy unidirectional flow	High-energy fluvial to tidal channel; compound dune field
	Sp (tabular sets)	Tabular cross-stratified medium- to coarse-grained sandstones; planar, laterally persistent set boundaries; foresets constant dip direction	Tabular planar cross-stratification; sharp planar bounding surfaces; straight-crested foresets	FA1 – Sandy bedload channel	Migration of straight-crested 2-D dunes under unidirectional flow	Fluvial to tidal channel; 2-D dune field
	St / Gt	Trough cross-stratified medium- to very coarse-grained sandstones and conglomerates; concave-up set bases	Trough cross-stratification; concave erosional base; biconvex to lensoidal foresets; pebble concentration at set bases	FA1 – Sandy to gravelly channel	Migration of 3-D sinuous-crested dunes and gravel dunes under unidirectional high-energy flow	Braided to tidal channel; 3-D dune migration
	Sl	Low-angle cross-bedded fine- to medium-grained sandstones; foresets <15°; locally tangential at base	Low-angle planar cross-stratification (<15°); tangential to angular foresets; locally current ripples on foresets	FA1 – Sandy bedload channel	Migration of low-relief washed-out dunes or antidunes; upper flow-regime conditions	Fluvial channel; upper flow regime
	Sp(h)	Herringbone cross-stratified sandstone with tidal bundles and mud drapes; bidirectional foreset dip; opposing cross-set orientations	Herringbone cross-stratification (opposing foreset dips); tidal bundles; double mud drapes; reactivation surfaces; asymmetrical current ripples	FA2 – Tidal dune / Intertidal sandflat	Reversing tidal currents; slack-water mud draping; neap–spring tidal bundle formation	Intertidal channel and tidal sandflat
	Sr / Sh	Asymmetrical ripple-laminated sandstone (Sr) and subhorizontally laminated sandstone (Sh); uppermost part of unit; wave ripples also locally present	Asymmetrical current ripple cross-lamination (Sr); symmetrical wave ripples; subhorizontal to horizontal lamination (Sh); locally climbing ripples	FA2 – Intertidal sandflat	Ripple migration under weak unidirectional currents (Sr); oscillatory wave influence; plane-bed traction (Sh)	Intertidal sandflat; waning tidal current
	Gm / Gt	Conglomerates as lenticular channelized bodies and bars; 5 cm–1 m thick; clasts up to 15 cm, subrounded to rounded; clast- to matrix-supported (Gmm locally)	Clast imbrication; low-angle cross-stratification; trough cross-stratification (Gt); faint horizontal stratification; lenticular geometry	FA1 – Gravel-bed channel lag	Bedload transport; clast imbrication records palaeocurrent; deposition from waning high-energy flood events	Braided fluvial channel; gravel-bar complex; channel-base lag
	Fl	Pelites and siltstones, 2–5 cm thick, intercalated within quartzite/sandstone beds; fine parallel to wavy lamination	Fine horizontal to wavy parallel lamination; sharp contacts with sandy beds	FA2 – Tidal flat / Slack-water drape	Suspension fallout during low-energy or slack-water tidal phases	Intertidal to supratidal mudflat; slack-water tidal drape

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Lower Siliciclastic– *Carbonate Unit (Ifrane-n-Taghatine Fm) 400–470 m*	**Fl / Sr / Fm**	Rhythmic heterolithic alternation of grey sandstone beds (cm–0.5 m) and siltstone to pelite (mm–5 cm); basal ~80 m; wavy to lenticular contacts; locally with chlorite alteration (bluish-green patches)	Wavy and lenticular bedding (flaser to wavy); desiccation crack polygons (mm–cm, orthogonal); current ripple marks (Sr); symmetrical wave ripple marks; soft-sediment deformation (Sm) locally	FA3 – Mixed intertidal flat	Alternating tidal traction (Sr) and suspension fallout (Fl, Fm); periodic subaerial exposure (desiccation); wave oscillation overprinting tidal flat	Intertidal flat transitioning to supratidal
	Sm	Fine- to very fine-grained sandstone (1–10 cm) and siltstone/pelite (mm–3 cm); ~40 m interval; abundant soft-sediment deformation; slump folds and load casts	Flaser and lenticular bedding; wavy lamination; current ripple marks; slump folds; load casts (bulbous, 3–8 cm); convolute lamination	FA3 – Tidal flat with slope instability	Tidal flat traction and suspension settling; soft-sediment deformation by gravitational loading and slope failure	Intertidal flat with slope instability
	Tuff (Tf) —	Intercalated pale green to beige fine-grained volcanic tuffs within siliciclastic strata; massive, grain-size distinct; sharp contacts with enclosing sediments; locally altered to green chlorite	Fine-grained ash; sharp lower and upper contacts; no internal grading; intact lamination of host sediment; locally fractured sub-vertically	FA3 – Pyroclastic intercalation	Contemporaneous volcanic ashfall or pyroclastic density current during tidal flat sedimentation; syndepositional volcanism	Tidal flat with volcanic activity
	Grainstone (Gs)	Massive to strongly structured grainstone beds, 5 cm–1 m thick; brownish-grey weathering patina; locally amalgamated; bounded by reactivation surfaces; intercalated with fine to medium siliciclastics	Horizontal stratification (Sh); planar cross-stratification (Sp); trough cross-stratification; bidirectional herringbone cross-stratification Sp(h); reactivation surfaces; internal bounding surfaces	FA4 – High-energy carbonate shoal	Wave and tidal current reworking on a high-energy shoal; reversing tidal currents (herringbone); grain-flow and traction (SMF 16–18, Wilson 1975; Flügel 2004)	Shallow subtidal to intertidal carbonate shoal / tidal bar
	Gs → Packstone (Ps) + Sp / Sh	Upper mixed carbonate–siliciclastic interval (200–250 m); increasingly sandy carbonates; pelite and siltstone interbeds progressively thickening upward; transition Gs → Ps	Planar cross-stratification (Sp); horizontal lamination (Sh); occasional herringbone; progressive upward thickening of siliciclastic beds; reactivation surfaces	FA4 – Carbonate shoal to mixed tidal flat	Tidal reworking of carbonate shoals; progressive siliciclastic influx upsection; Gs → Ps reflects decreasing energy or increasing mud input	Shallow subtidal carbonate platform transitioning to mixed tidal flat
Quartz Sandstone Unit *(Oumoula Fm) 700–900 m*	**Gm / Gt**	Lenticular conglomerates up to 4 m thick; clast- to matrix-supported; clasts ≤12 cm; thin stratified beds (1–10 cm) clast-supported with pebbles <4 cm; sharp erosional basal contact documented	Poorly developed normal grading; trough cross-stratification (Gt); horizontal stratification; clast imbrication; lenticular geometry; sharp scoured base	FA5 – Tidal to fluvial channel base	Debris flow to bedload traction; Gm = mass-flow or waning flood; Gt = traction-current; imbrication records palaeocurrent	Fluvial channel-base lag; tidal channel erosional base
	Sp / Sl / Ss	Coarse-grained sandstones; planar to very low-angle cross-stratification; foresets 10°–30° (tangential); locally dark/black due to Fe-oxides (hematite,	Planar cross-stratification (Sp); low-angle cross-stratification (Sl); broad basal scours (Ss); reactivation surfaces; laminae in bundles; desiccation cracks (2–8 cm, hexagonal); wave	FA5 – Tidal/fluvial channel and sandflat	Unidirectional bedload traction; scour-fill (Ss); reactivation surfaces record tidal asymmetry; periodic exposure; Fe-oxide enrichment in intertidal zone	Tidal to fluvial channel; intertidal sandflat

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		magnetite); eroded sandstone and pelite rip-up clasts	and current ripples; imbricated pebbles; rip-up clasts			
	Sp(h) / Sr	Medium- to fine-grained sandstones; tabular cross-stratification with colour/grain-size-differentiated foresets; double mud drapes; bidirectional foresets	Tabular planar cross-stratification; herringbone cross-stratification Sp(h); double mud drapes along laminae; reactivation surfaces; coexisting wave and current ripples (Sr); desiccation cracks on bedding planes	FA6 – Intertidal tidal dune and sandflat	Reversing tidal currents generating herringbone Sp(h); slack-water mud draping; neap–spring cyclicity; wave influence during fair weather	Intertidal tidal dune and sandflat
	Sh / Sl / Sr	Fine-grained sandstones; continuous beds or lenticular bodies; rhythmically alternating light and dark beds; small symmetrical ripples locally	Horizontal to very low-angle lamination (Sh, Sl); fine wavy laminae; small symmetrical ripples; herringbone cross-stratification; wavy laminations; wave and current ripple marks (Sr); rhythmic light/dark colour banding	FA6 – Shallow subtidal to intertidal	Oscillatory and combined flow (wave + tidal); plane-bed traction (Sh) at upper flow regime; rhythmic cyclicity from tidal or seasonal variations	Shallow subtidal to intertidal; wave-influenced tidal flat
	Fm / Fl / Sr (Shcs rare)	Pelites, shales, and very fine-grained sandstones; thin beds mm–40 cm; enriched in quartz, chlorite, muscovite; desiccation cracks 3–8 cm (hexagonal to irregular polygons); rare hummocky cross-stratification	Desiccation cracks (2–8 cm, polygonal network); current ripple marks (Sr); raindrop impressions; hummocky cross-stratification (Shcs, rare); interference ripples; rip-up clasts in overlying sandstones	FA7 – Supratidal to storm-influenced flat	Suspension fallout and subaerial exposure (Fm, Fl); episodic storm-wave oscillation (Shcs); periodic emersion; sheet-flood reworking of mudflat	Supratidal mudflat; storm-dominated intertidal fringe
Upper Siliciclastic– *Carbonate Unit (Tizi n'Taghatine Group) 300–600 m*	**Fl / Sh + Bindstone (microbial laminite)**	Lower carbonate-siliciclastic: heterolithic fine-grained sandstones (1–15 cm), siltstones and shales (mm–2 cm); upsection carbonate intercalations with planar and small domal stromatolites and microbial laminations	Desiccation cracks; horizontal lamination (Sh); wavy bedding (Fl); planar cross-stratification; microbial laminations; planar and small domal stromatolites (Grotzinger, 1989)	FA8 – Intertidal carbonate flat	Tidal flat traction and suspension settling; microbial mat accretion in intertidal to shallow subtidal settings (Grotzinger 1989; SMF 19–20, Wilson 1975); periodic subaerial exposure	Intertidal carbonate flat; shallow subtidal microbial platform
	Fl / Sr / Shcs	Middle heterolithic interval (~100–150 m): rhythmic fine-grained sandstone beds (0.2–10 cm) interbedded with siltstone and argillite (mm–1 cm); mud and sand intraclasts; locally storm-related deposits	Desiccation cracks; current and wave ripple marks (Sr); wavy and lenticular bedding (Fl); hummocky cross-stratification (Shcs); mud and sand intraclasts	FA9 – Mixed intertidal–storm influenced	Combined tidal and storm wave oscillation; suspension settling; episodic storm events (Shcs); reworking of intraclasts	Intertidal flat with episodic storm influence
	Sh / Sr / Sp	Quartz sandstone interval (10–30 m): fine- to medium-grained, rhythmically arranged light and orange beds (mm–5 cm); interbedded with argillite (mm–2 cm)	Wave ripple marks (Sr); horizontal laminations (Sh); wavy bedding; planar cross-stratification (Sp); rhythmic light/orange colour banding	FA6 – Intertidal sandflat	Oscillatory wave reworking and plane-bed traction; rhythmic alternation reflecting tidal or seasonal cyclicity	Shallow intertidal sandflat

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	Columnar Stromatolite Boundstone (CSB) + Intraclastic Rudstone (IR) + Sr / Shcs	Upper carbonate-siliciclastic interval (150–250 m): interbedded carbonates, green shales, heterolithic intervals; abundant columnar and domal stromatolites; flat-pebble conglomerates; tepee structures in siliciclastic intervals	Columnar and domal stromatolites; planar microbial laminations; current ripples (Sr); planar and hummocky cross-stratification (Shcs); wavy bedding; flat-pebble conglomerates (intraclastic Rudstone); wave ripple laminations; tepee structures	FA10 – Shallow carbonate platform	Microbial mat accretion (CSB – Grotzinger 1989; SMF 9, 19–20 – Wilson 1975); storm-wave reworking (Shcs); tidal current traction (Sr); subaerial exposure and early cementation (tepee structures); hydraulic reworking of lithified crusts (flat-pebble Rudstone)	Shallow carbonate platform: open subtidal lagoon → intertidal stromatolitic flat → supratidal exposure
	Sh / Fl / Sr / Sp	Upper heterolithic interval (~100 m): alternating fine-grained sandstone, siltstone, and shale; capped by 3-m-thick quartz-sandstone bed; horizontal stratification and wavy bedding dominant	Horizontal stratification (Sh); wavy bedding (Fl); desiccation cracks; planar cross-stratification (Sp); current ripple marks (Sr)	FA9 – Mixed intertidal–supratidal	Tidal flat traction and plane-bed sedimentation; suspension settling; periodic subaerial exposure (desiccation); terminal progradation of supratidal flat	Intertidal to supratidal flat