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Sedimentary Structures and Paleocurrent Analysis of the Ilaro Formation in the Dahomey Basin, Southwestern Nigeria

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Abstract: Detailed sedimentological studies of the Ilaro Formation from the Ajegunle, Papalanto, and Ifo outcrops in the eastern Dahomey Basin, southwestern Nigeria, were undertaken to interpret depositional processes and paleoflow patterns. The formation comprises medium- to coarse-grained cross-bedded sandstones with clay drapes, reactivation surfaces, and rare mudstone interbeds. Measured paleocurrent azimuths from cross-bed foresets indicate a dominant NE–SW paleoflow direction, implying sediment derivation from the inland Precambrian basement complex towards the Atlantic margin. Vertical facies successions show upward-fining cycles, typical of meandering fluvial channels that evolved into tidally influenced environments near the paleo-shoreline. The combined evidence supports deposition in a mixed fluvial–tidal system, consistent with the Paleogene paleogeography of the Dahomey Basin.

Keywords: *Ilaro Formation, Sedimentary structures, Paleocurrent analysis, Dahomey Basin, Fluvial–tidal transition, Paleogene Nigeria.*

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I. INTRODUCTION

The Ilaro Formation, a Paleogene sedimentary unit in the eastern DahomeyBasin(Fig.1) represents one of the most significant post-depositional stages of the basin’s evolution. It unconformably overlies the Ewekoro Formation and is overlain by the Coastal Plain Sands (Omatsola & Adegoke, 1981; Reyment, 1965). The formation consists predominantly of sandstones, siltstones, and occasional clay lenses that reflect dynamic depositional processes within a marginal marine setting.

Despite its extensive surface exposure in southwestern Nigeria, the paleoflow regime and depositional hydrodynamics of the Ilaro Formation remain under-documented. Understanding the paleocurrent patterns and sedimentary structures is essential for reconstructing the paleogeography and paleohydrology of the Paleogene Dahomey Basin.

This study therefore aims to:

- Describe the sedimentary structures preserved in the Ilaro Formation;
- Determine the dominant paleocurrent directions from cross-bedding data; and
- Interpret the hydrodynamic conditions and depositional environments in relation to the regional geologic framework.

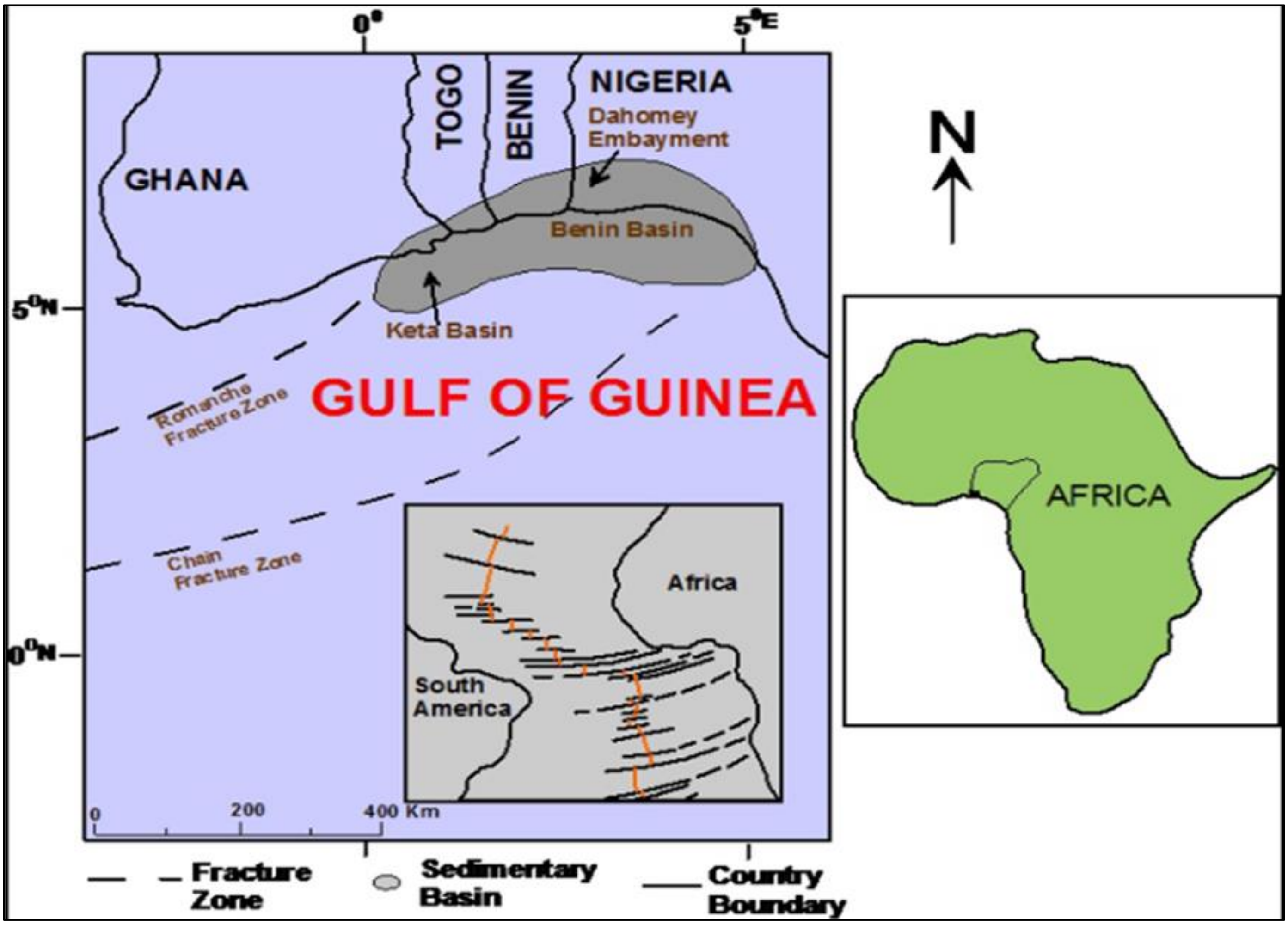

Fig 1 Dahomey Basin is Shown on a Regional Gulf of Guinea Map in Respect to Other Basins (Adapted from M.E. Brownfield et al. 2006)

II. GEOLOGICAL SETTING

The Dahomey Basin is a marginal (peripheral) sedimentary basin extending from southeastern Ghana across Togo and the Benin Republic into southwestern Nigeria, where it merges with the Niger Delta Basin. It occupies the upper Gulf of Guinea, bounded to the south by the Atlantic Ocean and to the north by the Precambrian Basement Complex. The basin originated during the Late Jurassic to Early Cretaceous as a result of rifting associated with the opening of the Equatorial Atlantic Ocean and the subsequent separation of the African and South American plates.

Structurally, the Dahomey Basin records four major tectono-sedimentary phases:

- Pre-rift (Late Jurassic) – characterized by continental sedimentation prior to crustal extension.
- Rift (Neocomian–Lower Cretaceous) – associated with faulting and graben development.
- Transitional (Cenomanian–Santonian) – marking a shift from continental to shallow marine deposition.
- Post-rift (Maastrichtian–Holocene) – dominated by stable marine and marginal marine sedimentation.

These stages correspond to rift, transitional, intracratonic, and drift depositional regimes. A significant transitional phase between the Cenomanian and Santonian marks the onset of open-marine conditions.

In Nigeria, the basin is delineated from the Niger Delta by the Okitipupa Ridge, a subsurface basement high linked to the Ilesha Spur, and bounded by the Benin Hinge Line fault zone (Adegoke & Omatsola, 1981; Eedawe & Coker, 1984). The basin's stratigraphic succession, ranging from Cretaceous to Recent, is exposed along a narrow arcuate belt parallel to the ancient coastline (Omatsola & Adegoke, 1981).

The Abeokuta Group forms the basal sedimentary unit, unconformably overlying the crystalline basement. It consists of sandstones, conglomerates, and kaolinitic clays, subdivided into the Ise Formation (Early Cretaceous fluvial deposits), the Afowo/Agwu Formation (Cenomanian shales and Turonian sandstones), and the Araromi Formation (Cenomanian–Maastrichtian marine shales). Overlying these are the Paleocene–Eocene carbonate and shale successions: the Ewekoro Formation (bioclastic limestone) and the Akinbo Formation (fissile shale and clay), which reflect shallow marine to lagoonal environments.

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Younger formations include the Oshosun Formation (Eocene phosphatic and sandy shales), the Ilaro Formation (cross-bedded, fine- to coarse-grained sandstones), and the Benin Formation (Miocene–Recent coastal plain sands). Collectively, these units record a progressive evolution from continental rift deposition to open-marine sedimentation, representing a complete petroleum system framework within the Dahomey Basin.

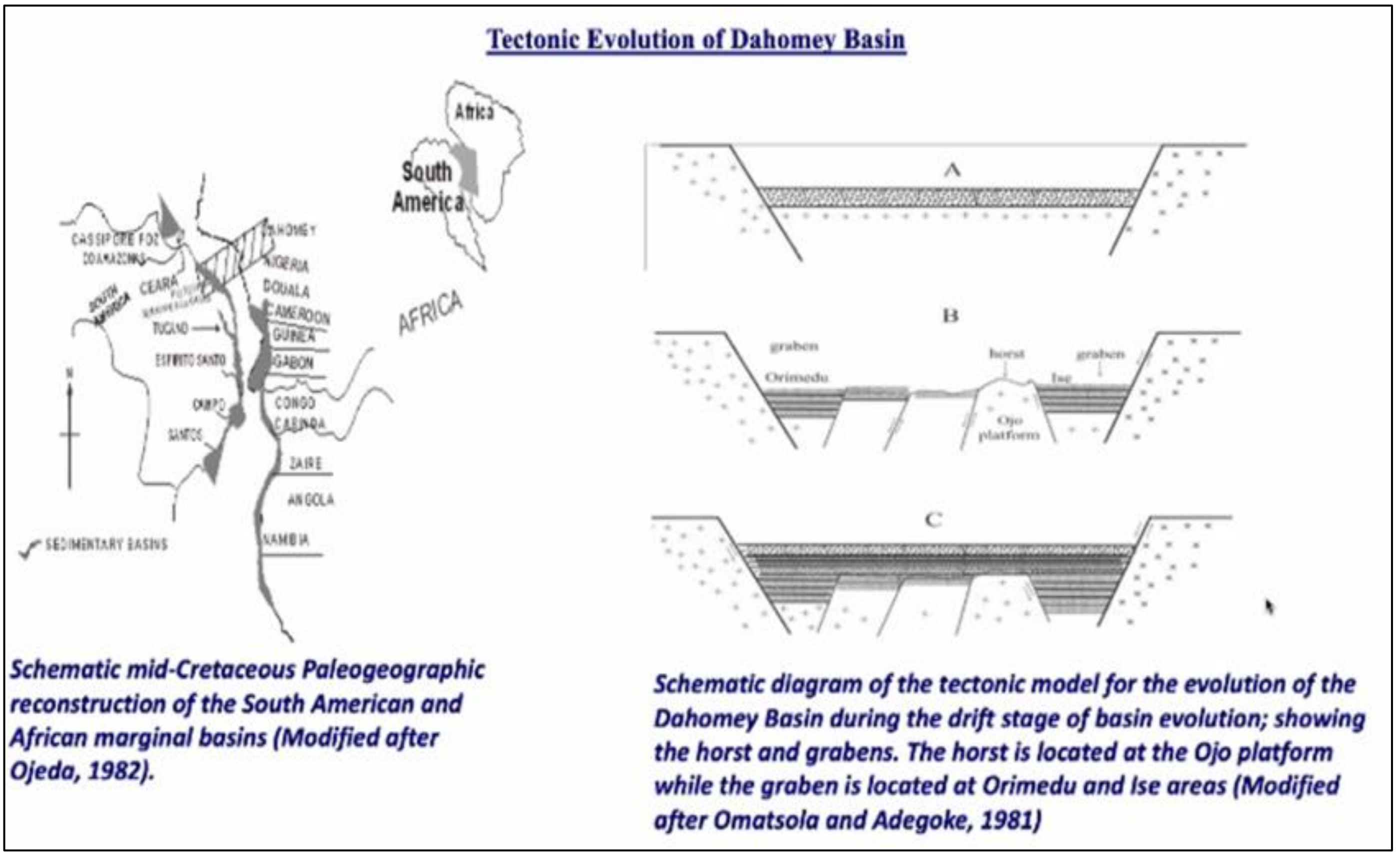

Fig 2 The Tectonic Evolution of the Dahomey Basin

III. STUDY AREA LOCATION AND FIELD METHODS

The study area encompasses key outcrop localities of the Ilaro Formation exposed at Ajegunle (6°55′N, 3°13′E), Papalanto (6°54′N, 3°10′E), and Ifo (Tecno Bus Stop; 6°49′N, 3°12′E) in Ogun State, southwestern Nigeria (Fig. 1b). These localities reveal well-exposed successions of cross-bedded sandstones intercalated with clay lenses, characteristic of the fluvial–tidal depositional regime of the Ilaro Formation.

The area is readily accessible via a network of major and minor roads connecting adjacent towns, facilitating systematic field investigation. The terrain is gently undulating, typical of the humid tropical rainforest zone of southwestern Nigeria. Present-day topography has been significantly modified by erosional processes, resulting in excellent natural exposures ideal for sedimentological logging and facies analysis.

During fieldwork, detailed sedimentary logs were constructed for each outcrop at a 1:50 vertical scale, documenting lithology, grain size, sedimentary structures, and vertical successions. Geological and location maps, including sampling points, were prepared using GPS coordinates recorded during the field survey (Figures 2 and 3).

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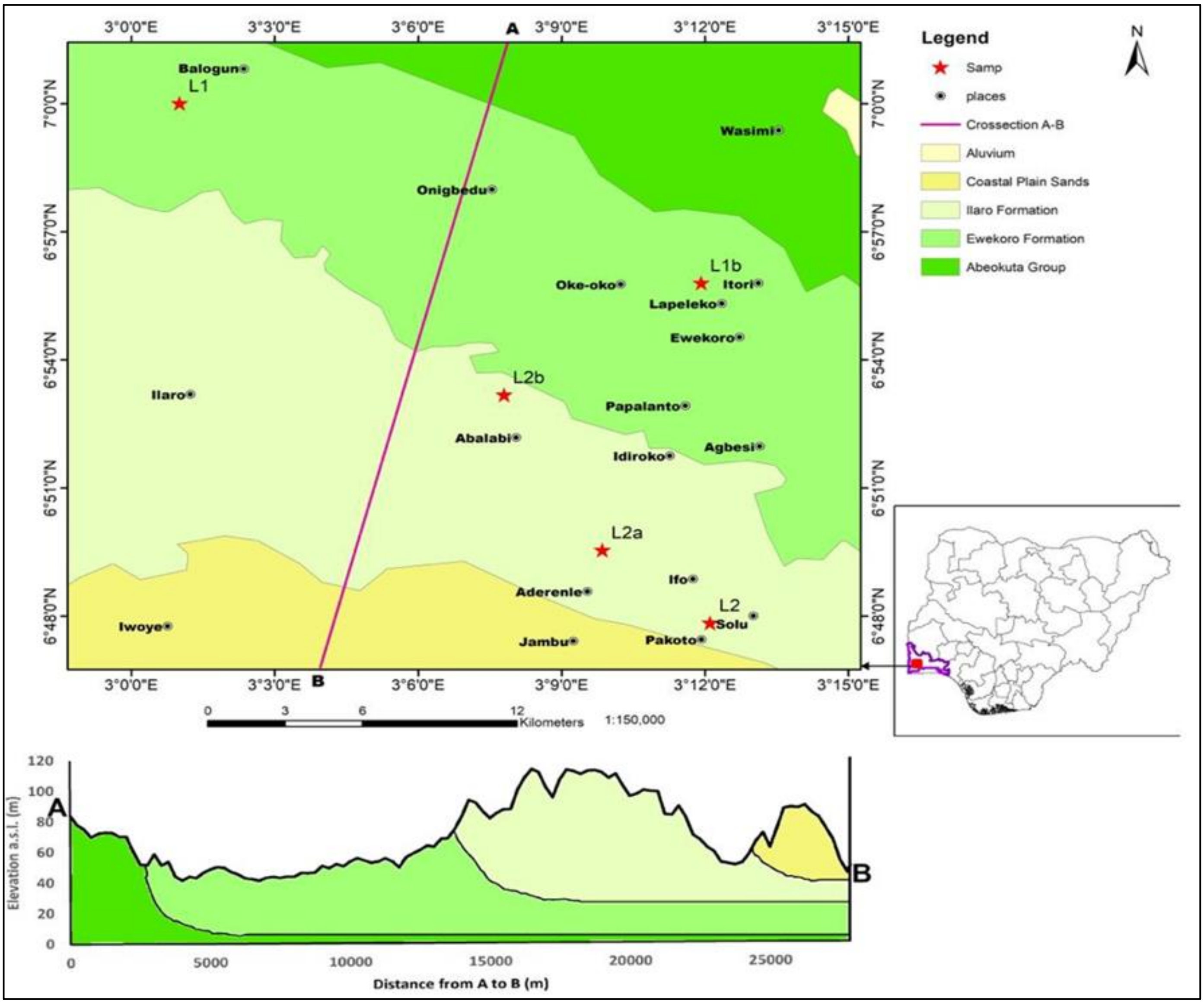

Fig 3 Geologic Map of Study Area.

➢ *Paleocurrent Measurements*

Paleocurrent analysis was carried out on cross-bedded sandstone outcrops within the study area to determine the principal paleoflow directions and sediment transport pathways. Measurements of foreset azimuths were obtained from well-exposed planar and trough cross-bedded units using a Brunton compass. At least 15 readings per outcrop were recorded to ensure statistical reliability. Each azimuth was corrected for dip direction to derive true paleoflow bearings.

The azimuth data were subsequently plotted as rose diagrams using 10° class intervals, and vector mean calculations were performed following the method of Potter and Pettijohn (1977). The vector mean direction (VMD) and circular standard deviation (CSD) were determined to assess the degree of dispersion in paleoflow orientation.

The resulting rose diagram (Fig. 4) indicates a dominant NE–SW paleoflow trend, consistent across the measured sections. The summarized paleoflow statistics for all sites are presented in Table 1.

Table 1 The summarized paleoflow statistics for all sites

Strike Id	**Direction**
AJE1	N78ºE
AJE2	N39ºE
PAPA1	S70ºE
PAPA2	S64ºE
IFO1	N9ºW
IFO2	N74ºE
IFO3	N56ºE

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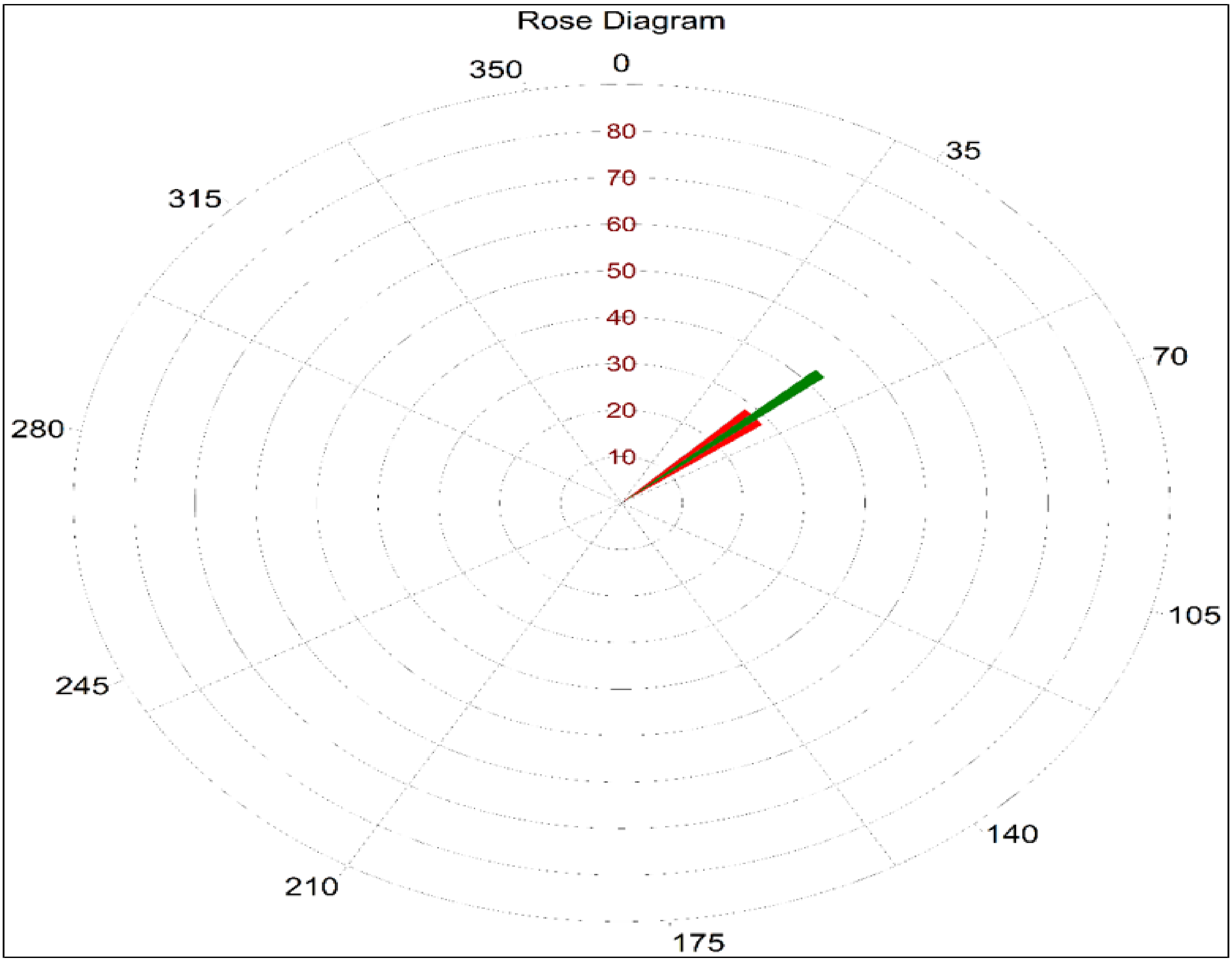

Fig 4 Rose Diagram of Paleocurrent Measurements Showing Dominant NE–SW Flow Direction.

- *Sources of Error and Mitigation*

The accuracy of sedimentological and paleocurrent analyses can be affected by both procedural and instrumental errors (Orousaye, 1980). Potential sources of error identified in this study include: Over- or under-sieving, leading to artificial fragmentation of coarser grains and inaccurate grain-size distribution; Clay lump retention, which may skew weight fractions in sieve analysis; Human error during measurement, data reading, or computational stages; and Instrumental bias arising from unclean or blocked sieve meshes.

To minimize these errors, samples were crushed gently and sieved for a maximum of ten minutes, avoiding grain attrition due to excessive shaking. Sieves were cleaned thoroughly after each use to prevent particle adhesion. All cross-bed measurements were taken perpendicular to bedding planes to reduce parallax errors, and repeated readings were used to confirm consistency.

These precautions ensured that measurement inaccuracies and operational biases were within acceptable analytical limits, thus preserving the integrity of the paleocurrent dataset.

IV. SEDIMENTARY STRUCTURES AND INTERPRETATIONS

Detailed field observations across the Ilaro Formation at Ajegunle, Papalanto, and Ifo reveal a variety of primary sedimentary structures that provide insights into depositional processes and paleoenvironmental conditions. These structures include planar and trough crossbedding, reactivation surfaces, bioturbation, clay drapes, intraclasts, and graded bedding, which are characteristic of high-energy fluvial to tidally influenced settings (Tucker, 2003; Stow, 2010).

- *Primary Sedimentary Structures*

The most common sedimentary structures observed (Plates 6–10) are planar cross-beds and trough cross-beds, which indicate unidirectional paleo flow and sediment transport by migrating ripples and dunes. These features commonly display clay drapes and reactivation surfaces, reflecting alternating phases of sediment deposition and erosion under variable flow conditions. The associated sandstones are moderately to poorly sorted, angular to sub-angular, and exhibit unimodal grain-size distributions, suggesting a single dominant transport direction (Plate 1).

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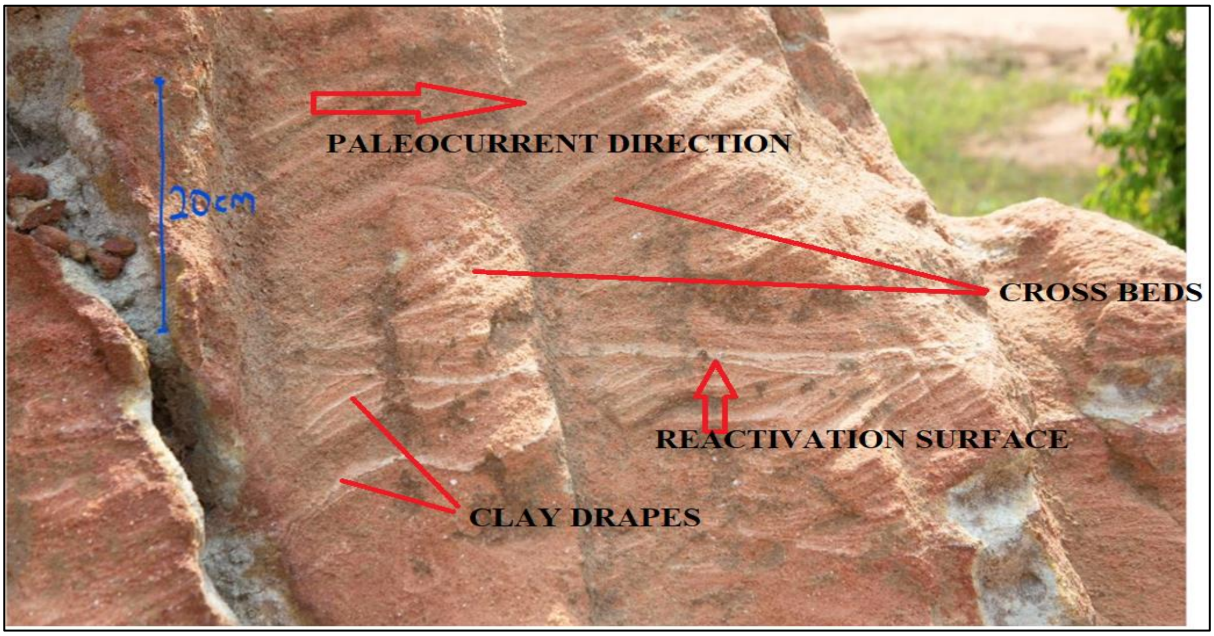

Plate 1 Sedimentary structures: cross beds and Paleocurrent direction, reactivation surface and Clay drapes observed in the Ilaro Formation in Ifon.

At Ajegunle, the outcrops reveal wavy lamination and burrow traces, interpreted as evidence of marginal marine influence and low-energy sedimentation in shallow subtidal to lagoonal environments (Plate 2). Such features form under slow sedimentation rates where biogenic reworking by benthic organisms is common (Boggs, 2009).

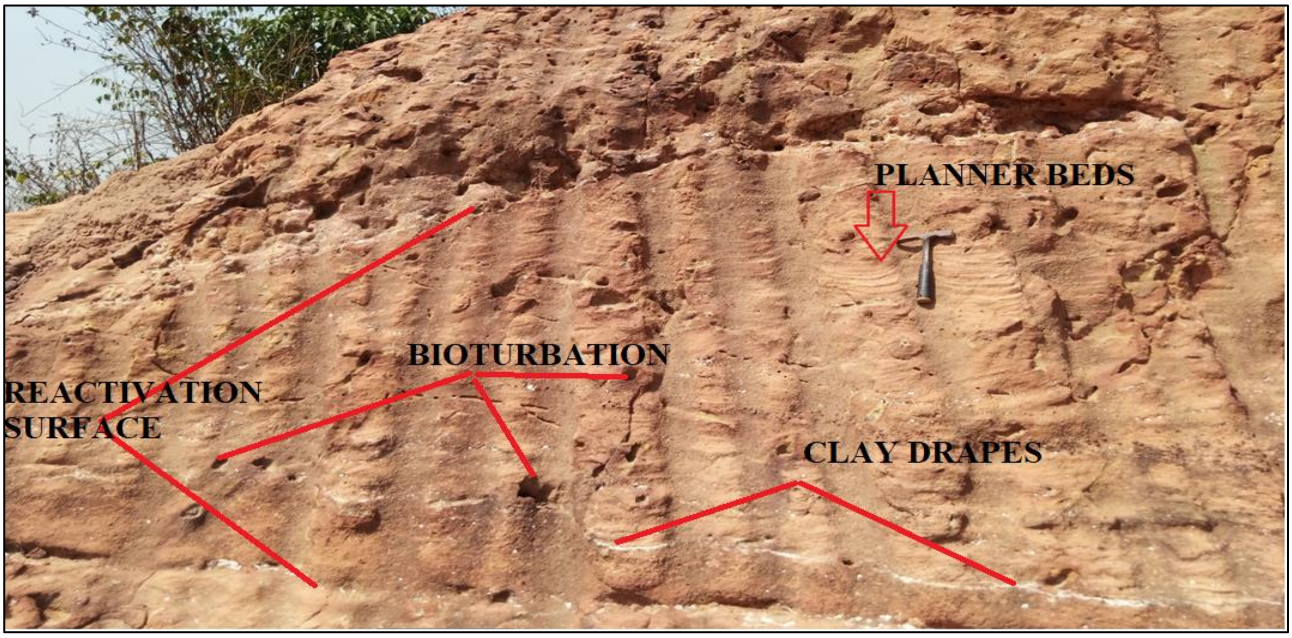

Plate 2 Sedimentary Structures observed in Ilaro Formation in Ajegunle

In Papalanto, cross-bedded units with vertical bioturbation structures (e.g., cylindrical burrows several centimetres in diameter) suggest active benthic colonization and post-depositional reworking of sediments (Plate 3). This bioturbation points to oxygenated bottom conditions and periodic subaqueous exposure during tidal fluctuations.

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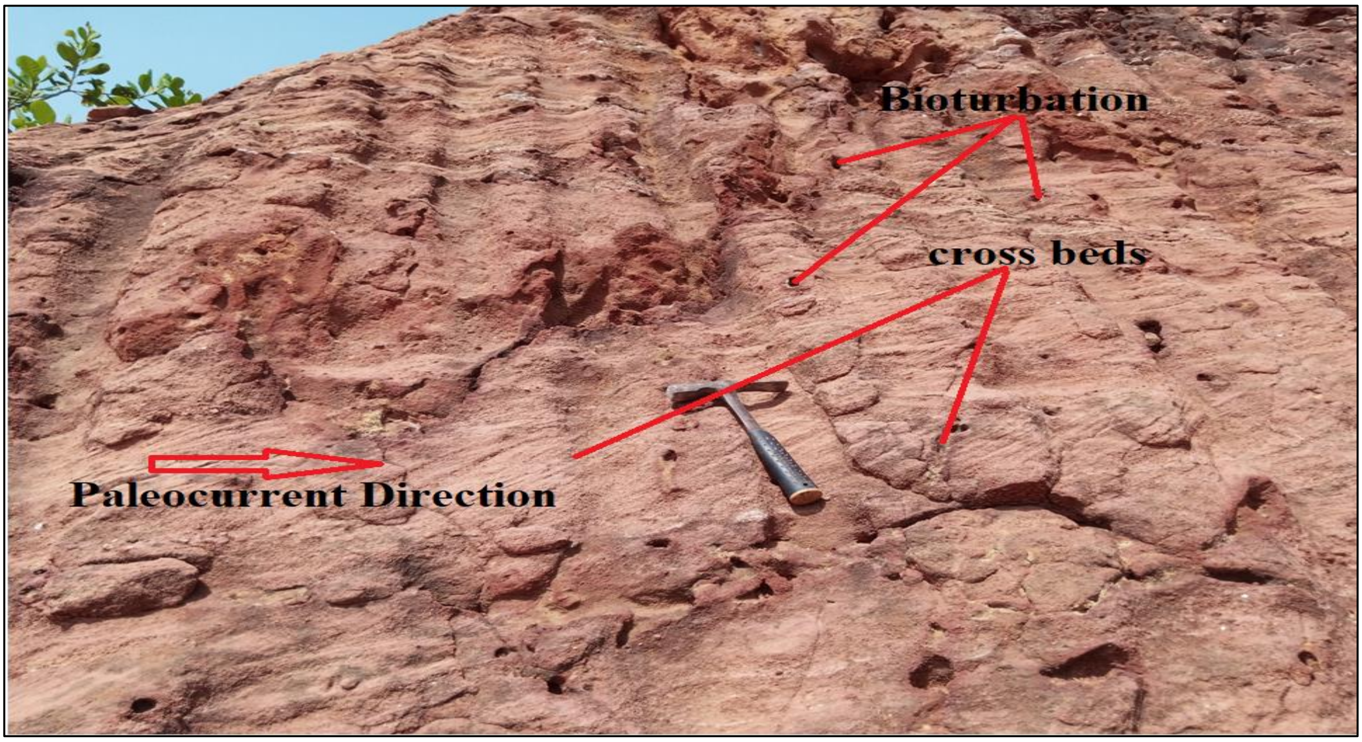

Plate 3 Sedimentary Structures and Paleocurrent Direction of Ilaro Formation in Papalanto

At Ifo, planar lamination, clay intraclasts, and cyclic sedimentary packages (Plate 4) indicate alternating depositional energy regimes—possibly linked to tidal or storm cycles. The occurrence of intraclasts suggests syndepositional erosion and reworking of semi-lithified sediments in shallow marine or tidal settings.

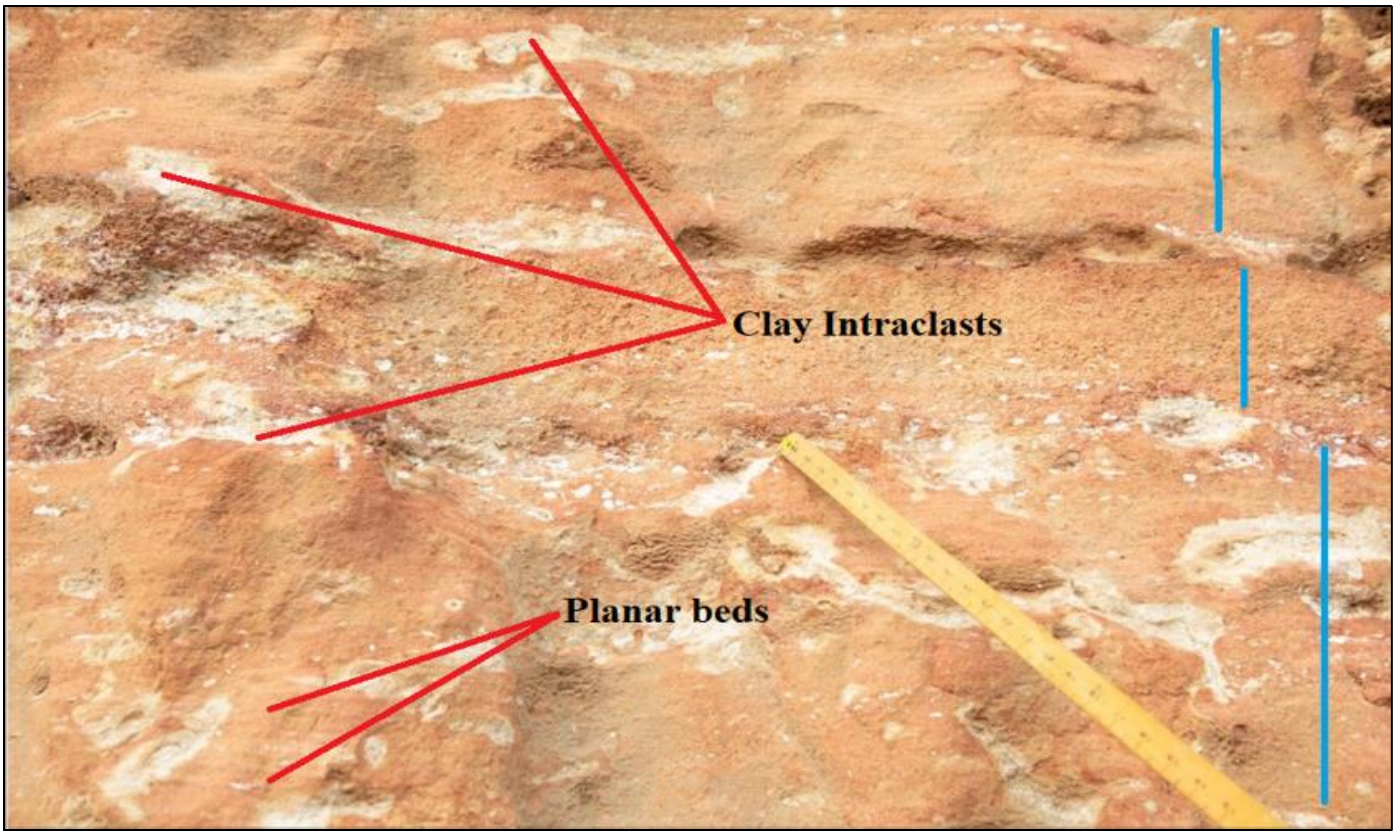

Plate 4 Sedimentary Structures in Ilaro Formation in Ifo, showing Planar beds, clay intraclasts. (Blue lines indicating cyclicity of sedimentary packages)

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Reactivation surfaces (Plate 5) and graded bedding were also observed. The latter shows upward fining of grain size, reflecting deposition from decelerating flows, typical of waning turbidity or flood events (Bouma, 1962). These structures collectively suggest repeated episodes of high-energy sediment input followed by quiescent periods of suspension settling.

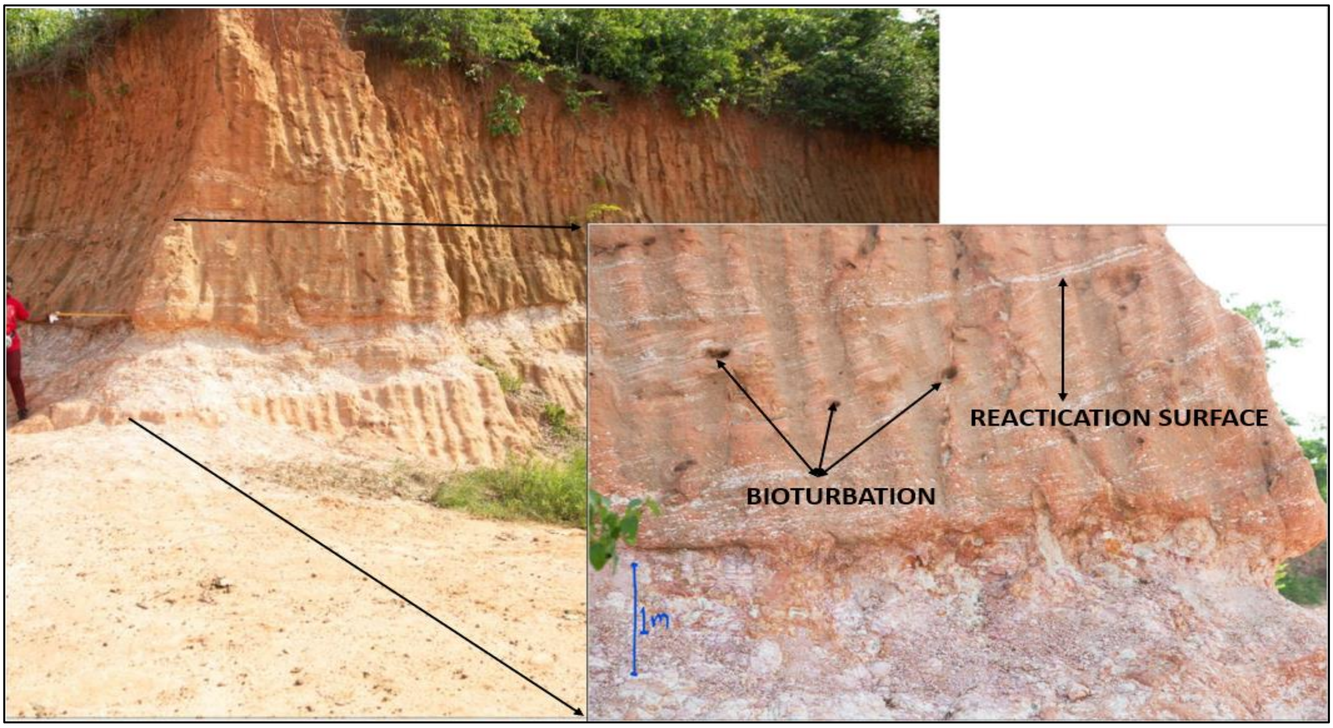

Plate 5 Sedimentary Structures, showing Reactivation Surfaces in Ilaro Formation in Ifo.

- *Paleocurrent Implications*

Directional sedimentary structures—particularly cross-beds and foreset azimuths—were used to infer paleocurrent orientations following the methods of Potter and Pettijohn (1977). The dominant NE–SW paleo flow trend (Fig. 13) indicates sediment transport from the inland crystalline basement high toward the Atlantic margin, consistent with a fluvial-dominated system influenced by tidal modulation.

V. PALEOCURRENT RESULTS AND INTERPRETATION

A total of 45 paleocurrent readings were analysed (15 per outcrop).

The results show a dominant paleo flow direction of 045°–060° (NE–SW) with minor NW and SE components (Fig. 2).

The paleocurrent pattern indicates a consistent northeast-to-southwest flow, implying sediment transport from the inland crystalline basement complex towards the coastal Dahomey Basin margin.

VI. DISCUSSION: FLOW REGIME AND TRANSPORT MECHANISMS.

The dominance of planar and trough crossbedding reflects tractional bedload transport under moderate to high flow velocities. The interbedded clay drapes and reactivation surfaces signify tidal reversals or periodic flow stagnation, indicating a fluvio-tidal transition zone.

The upward-fining sequences represent channel abandonment cycles, consistent with deposition in low-sinuosity to meandering channels. Such facies assemblages typify the upper to middle estuarine zones, where tidal energy begins to influence fluvial discharge.

- *Regional Paleogeographic Implications*

The north-eastward paleo flow direction supports previous models (Omatsola & Adegoke, 1981; Okosun, 1990) that infer progradation from the Nigerian shield into the Atlantic margin during Paleogene regression.

This is consistent with deltaic and estuarine deposition under a humid tropical climate, with strong seasonal river discharge modulated by tidal activity.

VII. CONCLUSION

The Ilaro Formation sandstones display sedimentary structures (planar and trough crossbedding, clay drapes, reactivation surfaces) indicative of high-energy, tidally influenced fluvial environments. Paleocurrent analysis reveals a consistent NE–SW sediment transport direction, implying provenance from the inland crystalline basement complex.

The vertical and lateral facies successions suggest meandering fluvial channels transitioning seaward into tidal flats and estuarine deposits. These findings align with the Paleogene paleogeography of the Dahomey Basin, reflecting a fluvio-marine system prograding toward the Atlantic Ocean.

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