Sequence stratigraphy of the Late Campanian – Early Maastrichtian Shiranish Formation, Jabal Sinjar, northwestern Iraq

Nabil Yousif Al-Banna

ABSTRACT

The Late Campanian – Maastrichtian Shiranish Formation consists of deep-marine marls and limestones that were deposited in northern and central Iraq. In northwestern Iraq, in the core of EW-trending Jabal Sinjar, a 430-m-thick section of the Shiranish Formation crops out. The base of the Shiranish section is not exposed here. It is unconformably overlain by Paleocene – Lower Eocene formations: Sinjar Formation along the northern part of the Jabal, and Aaliji Formation along its eastern side. Eighty samples were collected from the section and used for facies analysis and biostratigraphic calibration. Previous studies of planktonic foraminifera recognized four biozones, which were confirmed in the present study: Globotruncanita calcarata Interval Zone, Globotruncanella havanensis-Rosita fornicata Partial Range Zone, Globotruncanana aegyptiaca Interval Zone and Gansserina gansseri Interval Zone. These zones are here calibrated in several geological time scales. Six facies were distinguishable throughout the section, representing shallow-marine, middle-shelf, outer-shelf and upper-bathyal environments. These environments were used to interpret six depositional sequences. The older five Shiranish sequences are fourth order and grouped into one third-order sequence, while the sixth and youngest Shiranish Sequence was of third order. This suggests that the studied section was deposited in about 5 million years between ca. 76.0–74.4 and 69.5–69.8 Ma. The correlation between the Shiranish sequences and those of the Aruma Formation in Saudi Arabia implies that the northern Arabian Platform was regionally flooded starting in the Late Campanian and ending in the Maastrichtian. In the study area, an unconformity straddles the Cretaceous – Tertiary (K/T) boundary and represent a hiatus of ca. 10 or more million years.

INTRODUCTION

The Late Campanian – Maastrichtian Shiranish Formation of Iraq is comprised of Marls and limestones deposited during a regional transgressive-regressive cycle. The Formation is widely distributed in the subsurface and at outcrop in parts of northern Iraq, and is coeval with several other formations in other parts of the country. These formations are diachronous and defined according to lithology; for example in northern Iraq: marls (Shiranish Formation, Jib’ab Marl), fore- or back-reef limestones (Bekhme, Aqra and obsolete “Pilsener” formations) and clastics (Tanjero Formation) (Dunnington, 1958-2005; van Bellen et al., 1959-2005; Jassim and Goff, 2006; Al-Mutwali et al., 2008). These formations can pass below, above or inter-tongue with one another. Moreover, a different set of Late Campanian – Maastrichtian formations are used in southern and western Iraq: Hartha, Tayarat and Digma formations. The resulting complex lithostratigraphic relationships between these units are not suitable for correlations, and best resolved by biostratigraphy and sequence stratigraphy.

The present study focuses on a 430-m-thick Shiranish section exposed in Jabal Sinjar, near Mamissa village, northwest of Sinjar city (Figure 1). The Jabal forms an anticline, which strikes about 75 km EW and is 10 km wide. Although the base of the Formation is not exposed in the Jabal, the section nevertheless does represent an important outcrop, which can be tied into other stratigraphic control points in the Arabian Plate. Accordingly, 80 samples were collected from the section and used to describe the lithology, biostratigraphy and facies of the Formation. Based on these attributes, a depositional model and sequence stratigraphic interpretation are proposed for the Formation. The final section attempts to calibrate the interpreted Shiranish sequences in various chronostratigraphic and regional schemes.
TYPE SECTION OF SHIRANISH FORMATION

The Shiranish Formation was first described by Henson (1940, unpublished report, in van Bellen et al., 1959–2005), from which we can review the type section.

Location and thickness: The type section, 227.8 m thick, crops out near Shiranish Islam village (Figure 1a), near Zakho city in northern Iraq, at 37°11'30"N and 42°50'30"E.

Lithology: The type section is divided into an upper unit, 99.0 m thick, consisting of blue marl, overlying a unit of 128.8 m of thin-bedded marly limestone. The beds are weathered in an atypical pale blue color.

Lower boundary: The Shiranish conformably overlies the Bekhme Limestone Formation; the contact is taken at the top of Shiranish dolomitized thin-bedded globigerinal limestone. Elsewhere the Shiranish may pass laterally into the Bekhme Formation.

Upper boundary: The Upper Paleocene – Eocene Aaliji (marl) Formation overlies the Shiranish Formation with apparent unconformity; a marked faunal break corresponds to the Cretaceous – Tertiary (K/T) boundary.

Figure 1: (a) Isopach – facies map of Upper Cretaceous rocks (after Dunnington, 1958, reprinted from GeoArabia, 2005) showing location of the studied section. See facing page for continuation.
Figure 1 (continued):
(b) Landsat image of Jabal Sinjar (NASA 2000, provided by GeoTech, Bahrain).
(c) Geological map of Jabal Sinjar (after Ma`ala, 1977).
**Age:** In the type section, Henson (1940, in van Bellen et al., 1959–2005) reported that planktonic foraminifera are abundant. The following species were represented; *Globigerina cretacea* (d’Orbigny), *G. aspera* (Ehrenberg), *G. globulosa* (Ehrenberg), *Rugoglobigerina* spp., *Pseudotextularia elegans* (Rzehak), *P. varians* (Rzehak), *Globotruncana arca* (Cushman), *G. fornicata* Plummer, *G. gansseri* Bolli, *G. leupoldi* Bolli and *G. stuarti* (de Lapparent). These species indicate a Late Cretaceous (Maastrichtian) age at the top, and a Maastrichtian or latest Campanian age at the base.

**STUDIED SECTION OF THE SHIRANISH FORMATION**

**Location and thickness:** The studied section of the Shiranish Formation crops out in the core of Jabal Sinjar (Figure 1), where it is 430 m thick; the lower contact is not exposed.

**Lithology:** The Shiranish Formation generally consists of dark-blue, friable marl, marly limestones, arenaceous limestones, marls and breccias. Previous studies of the Formation in the Sinjar area divided the formation into three units (Al-Rawi, 1973). Field observations of the studied section confirm the easy recognition of these three units as follows.

- **Lower unit,** 45 m thick, consists of dark blue friable marl; the internal color is grey to brown. The lower boundary is not exposed, while the upper boundary grades to pale brown, tough and marly limestone that form the lower part of the middle unit.

- **Middle unit,** 285 m thick, embraces an alternating succession of marly limestones, arenaceous limestones, marls and breccias of pale brown to brown color; bed thicknesses range between 0.5–2.0 m (Figures 2 and 3). The arenaceous limestone is laminated and clearly distinguishable in the field by alternating dark brown to light gray lamina. In the middle of the unit, there is an interval of pale blue marly limestone bearing an abundance of ammonite shells. The unit contains six thin beds of breccia, less than 0.25 m thick, which extend for several 10s of meters. The lithoclasts consist of limestone rock fragments and quartz. They diminish in size upward and the breccias are followed by arenaceous limestones.

![Figure 2: Alternating marly limestones, limestones and marls in middle unit of the Shiranish Formation, Jabal Sinjar.](image-url)
• **Upper unit**, 100 m thick, is characterized by white to yellowish, laminated marl and marly limestone beds (Figure 4). The lower boundary is taken at the top of the last brown limestone of the middle unit, while the upper unconformable boundary is between the Shiranish Formation and the massive limestones of Tertiary Sinjar Formation (represented by a conglomerate bed 0.3 m thick); it marks the (K/T) boundary.

**Lower boundary**: The lower boundary is not exposed; however in subsurface sections at Ain Zalah-12 (Figure 1), Butmah, Adaiya and in northeastern Syria (Ghouna-1 well), the Shiranish Formation rests disconformably, but locally with erosional unconformity, on the Lower Campanian Mushorah Formation (van Bellen et al., 1959–2005).

**Upper boundary**: The upper boundary is unconformable with the Upper Paleocene – Eocene Sinjar Formation (van Bellen et al., 1959–2005; Youash and Nocum, 1970) (Figure 5). In the eastern plunge of the Sinjar Anticline, the Paleocene - Lower Eocene Aaliji Formation unconformably lies over the Shiranish Formation (van Bellen et al., 1959–2005; Ma’ala, 1977). R. Wetzel and H.V. Dunnington (*in* van Bellen et al., 1959–2005) noted that in Jabal Sinjar the larger part of the Maastrichtian is absent. They added that in general where the Shiranish is the uppermost Cretaceous formation its topmost units have been removed by erosion; but there is seldom any apparent angular unconformity.

Figure 3: Breccia bed in the middle unit of the Shiranish Formation, Jabal Sinjar.

Figure 4: Laminated marly limestones in the upper unit of the Shiranish Formation, Jabal Sinjar.

Figure 5: The unconformable contact between Shiranish and Sinjar formations in Jabal Sinjar.
The Shiranish Formation contains six facies, denoted Sh1 to Sh6, for which the sedimentological and biological evidence is used to determine their depositional environment and bathymetry.

Facies Sh1: Planktonic Foraminiferal Lime Mudstone

The allochems of this facies represent less than 10% of the facies content and is dominated by globular planktonic foraminifera represented by *Heterohelix, Globigerinelloides, Rugoglobigerina* and *Hedbergella*, in addition to benthonic foraminifera and echinoderm spines (Figure 8). The matrix consists of micrite with foraminiferal chambers filled by microspare cement or iron oxide as an oxidation product of Haq et al. (1988).
autochthonous glauconite mineralization. The biological and sedimentological attributes point to the mid-outer shelf depositional environment of the facies, based on an increase in the ratio of *Heterohelix* to *Globigerinelloides* species (Leicke, 1987).

**Facies Sh2: Globular Chamber Planktonic Foraminiferal Lime Wackestone**

This facies is characterized by marly limestone with thickness ranging between 20–60 m and an allochems percentage ranging between 20–40% of the total facies content. The facies consists primarily of globular foraminifera species belonging to *Heterohelix, Globigerinelloides, Rugoglobigerina* and *Hedbergella* genera, with few benthonic foraminifera and echinoderm spines (Figures 9). Horizontal lamination of allochems is attributed to the winnowed planktonic foraminifera tests. The percentage and the diversity of planktonic foraminifera increase upward. All the attributes indicate an outer-shelf environment with depth ranging between 100–200 m (Berggren and Miller, 1989).

**Facies Sh3: Keeled Planktonic Foraminifera Lime Wackestone**

The allochems consist primarily of keeled forms of planktonic foraminifera represented by *Globotruncanina, Globotruncanella, Globotruncanita, Rosita* and *Gansserina*. They constitute 75% of the total planktonic foraminifer’s population. These genera have normal size and good preservation. Rare globular planktonic foraminifera and benthonic foraminifera were also present.

The depositional environment of this facies is interpreted as an outer-shelf to upper–bathyal environment with water depth ranging between 150–300 m. These limits are based on the diversity of planktonic foraminifera and keeled/globular ratio, which increased or decreased upward depending on the transgressive or regressive development of the facies.
Facies Sh4: Ammonite Wackestone

This facies is characterized by marly limestone bearing abundant ammonite shells attributed to *Exiteloceras*, *Diplomoceras*, *lewyites*, *Parasolenoceras*, *Baculites*, *Nostoceras*, *Solenoceras*, *Hauericeras*, *Nostoceratid* and *hanericeras* (Kennedy and Lunn, 2000; Al-Bdrani, 2001) (Figure 10). Generally, the occurrence of ammonite genera implies an outer–shelf to upper-bathyal environment (Westerman and Tsujita, 1999). The matrix consists of micrite dominated by globular planktonic foraminifera. Their percentage decreases upward and shell fragments appear in the upper part of the facies. Trace fossils of inclined burrows are distinguishable by dark-colored fill material. The percentage of the ammonite genera diminished upward (Al-Bdrani, 2001). These attributes point to an upper-bathyal environment in the lower portion and a gradual change to an outer–shelf environment in the upper portion of the facies. The facies occurs in the middle unit and is 50 m thick.

Facies Sh5: Planktonic Foraminifera Lime Packstone

This facies consists of brown to pale brown marly limestone, in which allochems make up 80% of the total content. They are primarily planktonic foraminifera expressed as *Globotruncana*, *Globotruncanella*, *Globotruncanita*, *Rosita*, *Gansserina*, *Heterohelix*, *Globigerinelloides*, *Rugoglobigerina* and *Hedbergella*. Shell fragments and small amounts of benthonic foraminifera are also present (Figure 11). In the lower part of the facies, lithoclasts are present above facies Sh5, with their grain size and percentage decreasing upward. The occurrence of planktonic foraminifera with a high percentage of bioclasts represents a shelf-margin environment with depth ranging between 150–200 m (Flugel, 2000).

Facies Sh6: Breccia

The final facies consists of subangular to angular pebbles ranging in size from a few millimeters to several centimeters. The lithoclasts include carbonate rock fragments bearing benthonic foraminifera, green algae (*Salpingoporella dinarica*), ostracods, and fish teeth, in addition to rhombs of dolomite (Figure 12). The carbonate rock fragments represent a shallow-marine environment. The extraclasts include glauconite, quartz and phosphate minerals (Figure 13). The matrix includes micrite-bearing planktonic foraminifera. This facies is found imbedded six times with other facies of the middle unit, with a thickness of up to 0.25 m and lateral extent of several 10s of meters. These paleontological and sedimentological attributes indicate that the source of the components were shallow-marine rocks that were eroded and deposited as lowstand fans by turbidity currents in the outer-shelf (Emery and Myers, 2006).

SEQUENCE STRATIGRAPHY

Six sequences, denoted Shiranish Sequences 1 to 6, are interpreted in the exposed section (Figure 14). They vary in thickness from 10–211 m and are described in terms of sequence boundaries (SB),
lowstand systems tracts (LST), lowstand fans (LSF), transgressive surfaces (TS), transgressive system tracts (TST), maximum flooding surfaces (MFS) or intervals (MFI), and highstand system tracts (HST).

**Shiranish Sequence 1**

The thickness of Sequence 1 is greater than 55 m (lower part is not exposed). It starts with 45 m of facies Sh3, which shows an increase in water depth upward. It is interpreted as the TST, with the MFS placed at its top. The overlying HST consists of marly limestone from facies Sh1. The sequence is terminated by a Type-1 boundary.

**Shiranish Sequence 2**

Sequence 2, 18 m thick, begins with the deposition of facies Sh6: lowstand fans by turbidity currents. This is followed by deeper-water marly limestones (facies Sh4 facies) accompanied by an increased abundance and greater diversity of planktonic foraminifera that represent the TST. The MFS is positioned in the middle of facies Sh4 where the maximum number of species is recorded. The HST is characterized by facies Sh1. The upper boundary is interpreted as SB Type-1.

**Shiranish Sequence 3**

This sequence, 60 m thick, commences with the deposition of facies Sh6 as LSF. It is followed by facies Sh1 that depicts an increase in water depth upward, as also indicated by the increasing number of planktonic foraminifera species. Both facies Sh6 and Sh1 are interpreted as the early TST. The overlying facies Sh5 is interpreted as the late TST. The MFS is represented by the top of facies Sh5, which displays the maximum number (30) of planktonic foraminifera species. It is followed by the deposition of facies Sh6 and Sh2 as the HST; the upper SB is Type-1.

**Shiranish Sequence 4**

Sequence 4, 53 m thick, commences with the deposition of facies Sh6 (LSF), which is assigned to the early TST. The remainder of the Sequence consists of facies Sh4, which shows a decrease in water depth upward as the proportion of bioclasts increases in the facies’ matrix. The diversity and percentage of ammonite species also decrease upward (Al-Badrani, 2001). The lower part of the facies is assigned to the TST and the upper part to the HST. The MFS is represented in the lower part of facies Sh4, where the extraclasts of facies Sh4 decreased and ended at the 160 m point. The upper SB is Type-1.

**Shiranish Sequence 5**

This sequence, 33 m thick, begins with the deposition of facies Sh6 as a lowstand fan deposit. It is followed by the deposition of facies Sh5 as a shelf margin wedge, which represents the TST. It is overlain by facies Sh2, which displays a shallow environment upward, suggesting the HST of the sequence. The MFS lies on the boundary between the two facies (Sh5 and Sh2); the upper boundary is Type-1.
**Shiranish Sequence 6**
The final sequence is 211 m thick and located in the upper part of the middle unit and upper unit. It starts with the deposition of a thin bed of breccia (Sh6) followed by the marly limestone of facies Sh2, generally increasing in depth upward. The overlying rock is represented by facies Sh3, and the TST is interpreted in Sh2 and the lower part of Sh3. The maximum flooding interval (MFI) is characterized by the diversity of planktonic foraminifera in which more than 50 species are found between intervals 335–350 m. The HST is represented by the upper part of facies Sh3 in which the keeled/globular (K/G) ratio of planktonic foraminifera decreases upward. The upper boundary is Type-1 below the massive limestone from the Sinjar Formation.

**CHRONOSTRATIGRAPHY AND REGIONAL CORRELATIONS**

**Time Calibration according to Geological Time Scales**

According to the geological time scale GTS 2004 of Gradstein et al. (2004), the four biozones of the studied section span the Late Campanian – Early Maastrichtian between ca. 76.0 and 69.8 Ma (Figure 14, Tables 1 and 2). Shiranish Sequence 1 to 4 are assigned to the *Globotruncanita calcarata* Interval Zone with an estimated age of ca. 76.0–75.6 Ma. Sequence 5 is assigned to the lower part of the *Globotruncanella havenensis* Partial Range Zone with an age between ca. 75.6 and 74.4 Ma. These time calibrations suggest that Sequences 1 to 5 were deposited in ca. 1.6 My and are of fourth-order. Sequence 6 spans the upper part of the *Globotruncanella havenensis* Partial Range Zone and ends in the *Gansserina gansseri* Interval Zone with an age between older than 74.4 to ca. 69.8 Ma and a depositional period of ca. 4.6 My.

In contrast, in the time scale of Li et al. (1999), the four biozones span ca. 74.8 to 71.0 Ma such that the six Shiranish Sequences would have a depositional duration of ca. 3.8 My (Table 2), compared to 6.2 My (Gradstein et al., 2004).

**Time Calibration according to Arabian Orbital Stratigraphy**

In the Arabian Orbital Stratigraphy (AROS) of Al-Husseini and Matthews (2008; Middle East Geologic Time Scale ME GTS 2008, Al-Husseini, 2008), the Shiranish sequences 1 to 6 might correlate to third-order sequences DS$_3^5$.1 and 5.2 (Table 2). Sequence 5.1 is predicted to start a regional second-order transgression (DS$_3^5$.5) above a major sequence boundary SB$_3^5$.3 at ca. 74.4 Ma. Sequence DS$_3^5$.1 and 5.2 are predicted to have a combined depositional period between 74.4 Ma (Late Campanian) and 69.5 Ma (earliest Maastrichtian) with a duration of 4.86 My. This time calibration compares well with that

| Table 2 | Studied Biozones and Chrono-sequences |
|---------|--------------------------------------|
| **GTS 2004** | Early Maastrichtian | Haq et al. (1988) | Li et al. (1999) | Jabal Sinjar This Study | Dohuk, Iraq Al-Mutwali et al. (2008) |
| **Late Campanian** | 70.6 ± 0.6 | 69.8 | 68.5 | 71.0 | 71.0 |
| | **G. gansseri** | 72.0 | 71.0 | 71.0 | 71.0 |
| | **G. aegyptiaca** | 74.4 | 72.5 | 74.0 | 74.0 |
| | **G. tricarinata** | 75.6 | 74.0 | 74.8 | 74.8 |
| | **Globotruncanita calcarata** | 76.0 | 75.5 | 74.8 |

**Saudi Arabia**

| Philip et al. (2002), Le Nindre et al. (2008) | Al-Husseini and Matthews (2008) |
| **Depositional Sequence SB$_3^5$.3** | 69.5 – 74.4 |

**Depositional Sequence DS$_3^5$.5** | 5.2 |
| **Depositional Sequence SB$_3^5$.2** | 5.1 |
### Late Campanian – Early Maastrichtian Shiranish Formation, northwestern Iraq

Figure 14: Lithology, biostratigraphy and sequence stratigraphy of the studied section of the Shiranish Formation, Jabal Sinjar, northern Iraq.
of Li et al. (1999) for the lower part of the Shiranish Formation (74.8 versus 74.4 Ma), and with that of Gradstein et al. (2004) for the upper boundary’s age (both 69.8 Ma).

Although our study does not include the base of the Shiranish Formation, as noted above it is interpreted as a disconformity in other representative sections, with probable local erosion cutting into the Lower Campanian Mushorah Formation (van Bellen et al., 1959–2005). It may therefore be a regional sequence boundary. The regional transgression in Jabal Sinjar is evident in Shiranish Sequence 1, which is interpreted to start with a 45-m-thick TST with facies Sh3 representing deposition in an outer-shelf to upper–bathyal environment with water depth ranging between 150–300 m (Figure 14).

If the correlation to the orbital AROS model is adopted (Table 2), then Shiranish Sequences 1 to 5 may be fourth-order sequences (405,000 years) and correspond to third-order sequence DS$^3$ 5.1. Al-Husseini and Matthews (2008) predicted that third-order sequences are formed by 5, 6 or 7 fourth-order sequences; five would apparently be consistent with the Shiranish Sequence 1 to 5. Shiranish Sequence 6 could then be DS$^3$ 5.2 and may be a long third-order sequence that lasted 2.835 My (7 x 0.405 My). In the orbital model the older third-order MFS of DS$^3$ 5.1 would occur in Shiranish Sequence 3 and have an age ca. 73.4 Ma. The MFS of DS$^3$ 5.2 would be positioned in the MFI of Shiranish Sequence 6 with an estimated age of 68.2 Ma (Table 2).

**Correlation to Arabian Plate Maximum Flooding Surfaces**

Sharland et al. (2001) considered MFS K170 as mid-Campanian (to locally early Late Campanian) and positioned it in the Shiranish Formation; but in the G. ventricosa Zone, which is older than the studied section. In the time scale of Gradstein et al. (2004), MFS K170 has an age of ca. 78.0 Ma (Simmons et al., 2007; Al-Husseini, 2007) and would not likely correlate with the oldest MFS of Shiranish Sequence 1. Sharland et al. (2001; M. Simmons, written communication in Al-Mutwali et al., 2008) tentatively placed MFS K175 in the basal Maastrichtian portion of the Shiranish Formation, which implies an age younger than 70.6 + 0.6 Ma. This age appears too young to correlate with the third-order MFI of Shiranish Sequence 6, in latest Campanian.

**Correlation to Bekhme Sequences, Dohuk Area, Northern Iraq**

Al-Mutwali et al. (2008) studied the Late Campanian Bekhme Formation in Dohuk, northern Iraq (Figure 1 and Table 2). It is, in part, an equivalent formation to the Shiranish Formation. They interpreted Bekhme Sequences 1 to 4 corresponding to the Globotruncanita calcarata and Globotruncanella havanensis zones. Their youngest Sequence 5 starts in the uppermost part of the Bekhme Formation and continues into the Shiranish Formation; it is also assigned to the Globotruncanella havanensis Zone. The biostratigraphic data suggests that Shiranish Sequences 1 to 5 in Jabal Sinjar (this study) are coeval to Bekhme Sequences 1 to 4. Moreover, it suggests that Shiranish Sequence 6 may be in part correlative to their Sequence 5, which straddles the upper part of the Bekhme and lower part of the Shiranish formations (Table 2).

**Correlation to Aruma Sequences, Central Saudi Arabia**

In central Saudi Arabia, the Aruma Formation at outcrop consists of the Khanasir, Hajajah and Lina members. Philip et al. (2002) interpreted the Khanasir Member as Aruma Sequence 1, Hajajah Member as Aruma Sequences 2 and 3, and Lina Member as Late Paleocene and Early Eocene Aruma Sequence 4 (Table 2). Le Nindre et al. (2008, and references therein) considered the Khanasir as latest Campanian – Early Maastrichtian in age on the basis of ammonite Sphenodiscus [Libicoceras] acutodorsatus found in the basal Aruma Formation, and nannoflora corresponding to nannofossil zones NC20 and NC21. They dated the Hajajah Member as latest Maastrichtian (Zone NC 23).

Zones NC20 and NC21 are equivalent to the Globotruncanita calcarata to Gansserina gansseri zones in Haq et al. (1988) and assigned to the latest Campanian and most of the Maastrichtian (Table 1). The age assignments adopted by Le Nindre et al. (2008) use this former convention, whereas in the scheme of Gradstein et al. (2004) the four zones are essentially assigned to the Late Campanian and earliest Maastrichtian.
From a biostratigraphic and regional point of view (Table 2), it seems likely that Aruma Sequences 1 and 2 correlate to Shiranish Sequences 1 to 6 and span the latest Campanian and Early Maastrichtian sensu GTS 2004 (Gradstein et al., 2004). A one-for-one sequence correlation is not possible at such great distances (c. 1,000 km); nevertheless it seems likely that Aruma Sequence 1 may correlate to Shiranish Sequences 1-5, and mark the start of regional transgression over most of Arabian Plate. Aruma Sequence 2 may correlate in part to Shiranish Sequence 6. Late Maastrichtian Aruma Sequence 3 may correspond to a hiatus of erosion in Jabal Sinjar. The Late Paleocene and Early Eocene Lina Member (Aruma Sequence 4) would correlate to the coeval Sinjar Formation.

CONCLUSIONS

Biostratigraphic analysis of the Late Campanian - Maastrichtian Shiranish Formation in Jabal Sinjar, northern Iraq, confirmed previous studies that identified four biozones (1) Globotruncanita calcarata Interval Zone, (2) Globotruncanella havanensis-Rosita fornicata Partial Range Zone, (3) Globotruncan aegyptiaca Interval Zone and (4) Gansserina gansseri Interval Zone. These zones, however, have been used in different ways to define the boundary between the Campanian and Maastrichtian stages (Table 1; Caron, 1985; Haq et al., 1988; Gradstein et al., 2004). The absence of a common convention for identifying this boundary causes much confusion for regional correlations across the Arabian Plate. Some authors follow the older schemes (Caron, 1985; Haq et al., 1988) and place the Campanian – Maastrichtian boundary between zones (1) and (2) (e.g. Sharland et al., 2001; Al-Joboury, 2002; Le Nindre et al., 2008, and references therein); others follow Gradstein et al. (2004) and place the boundary within zone (4) (Al-Mutwali et al., 2008; this study).

This paper seeks to clarify this confusion at the Jabal Sinjar locality. It shows the studied section and four biozones correspond to six facies that reflect depositional environments ranging from shallow-marine to upper-bathyal. The environments correspond to six depositional sequences in Jabal Sinjar, which are Late Campanian and Early Maastrichtian sensu GTS 2004 (Gradstein et al., 2004). The Late Campanian Shiranish Sequences 1 to 5 are fourth order and group into one third-order sequence. Shiranish Sequence 6 is third-order and spans the Campanian – Maastrichtian boundary. Various age calibrations for the four biozones, depositional sequences and MFS suggest that the Shiranish Formation in Jabal Sinjar has an age between Late Campanian (ca. 76.0–70.6 Ma) and Early Maastrichtian (ca. 70.6–69.8 Ma). In Jabal Sinjar, the lower part of the overlying formations are Late Paleocene (younger than ca. 59.0 Ma in GTS 2004 implying a hiatus of ca. 10 or more million years across the Cretaceous – Tertiary (K/T) boundary.

ACKNOWLEDGMENT

The author would like to thank M.M. Al-Mutwali and two anonymous GeoArabia reviewers for their valuable comments. He also thanks GeoArabia’s Editor-in-Chief, Moujahed I. Al-Husseini, for his helpful editing and comments, and GeoArabia’s Production Manager, Nestor Buhay II, for designing the manuscript. The Landsat image of Jabal Sinjar in Figure 1b (NASA 2000) was kindly provided by GeoTech, Bahrain.

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ABOUT THE AUTHOR

Nabil Yousif Al-Banna holds a BSc in Geology (1978), MSc (1983) in Sedimentology (clastics) and a PhD (1997) in sedimentology (carbonates) from Mosul University, Iraq. Between 1983 and 1998, Nabil worked as a Geologist in the Underground Storage Team of the Iraq Oil Company. In 1999, he moved to Mosul University as a Lecturer at the Dam and Water Resource Research Center. He has supervised many PhD students in his areas of expertise and participated in various geological projects. Since 2000, Nabil’s main research interests have been sedimentology and sequence stratigraphy of the Mesozoic and Cenozoic.

n_albanna2005@yahoo.com

Received Manuscript November 23, 2008; Revised May 16, 2009

Accepted June 10, 2009; Press version proofread by the author on July 12, 2009