

## Carbonate reservoir characteristics and porosity distribution in Souedih Oilfield, Northeast Syria

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### ABSTRACT

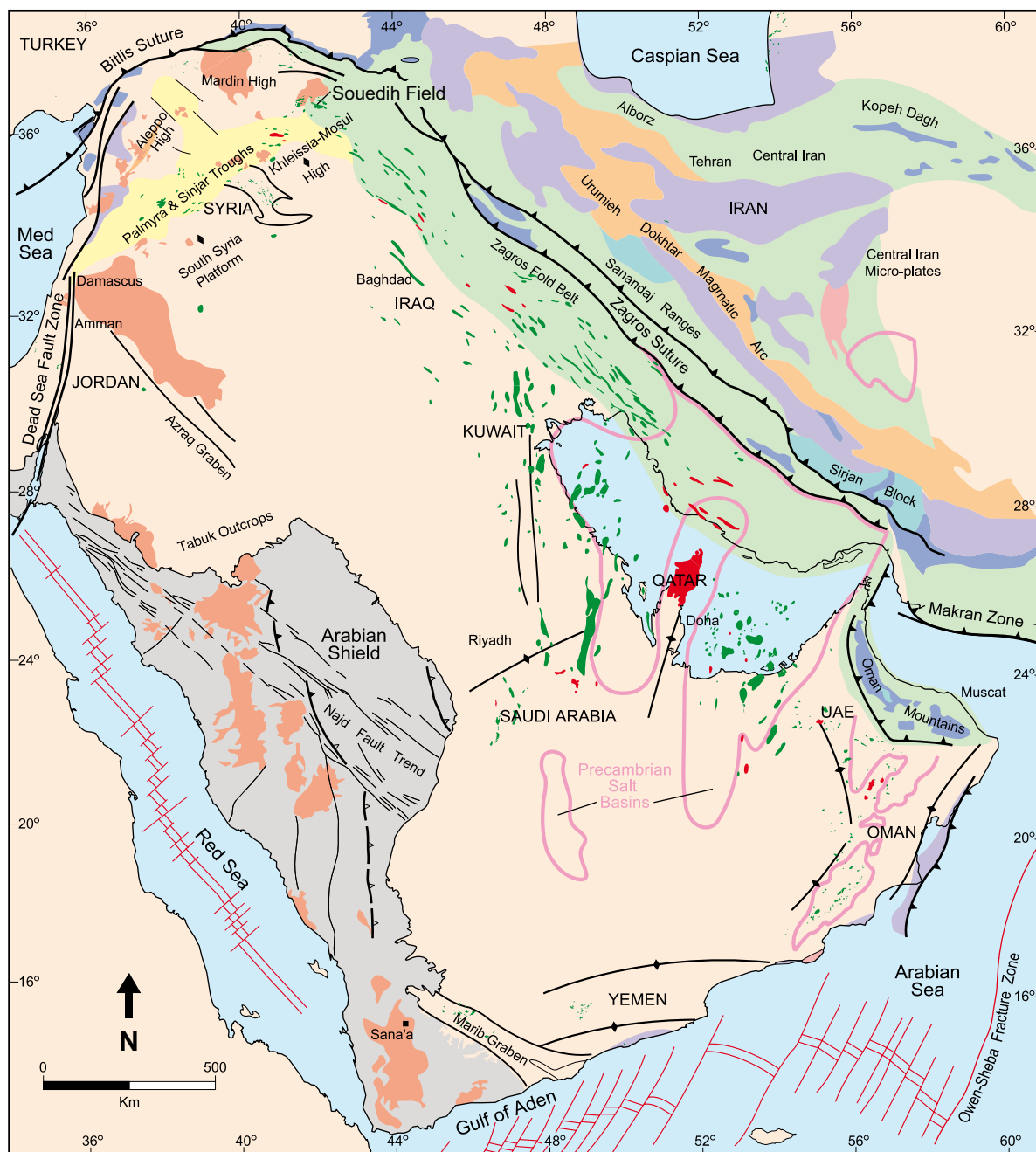
The Souedih (also spelled Suwaidiyah) Oilfield is located in the extreme northeast of Syria in part of the Mesopotamian Basin. The principal reservoir of most fields in this region is the Upper Cretaceous, carbonate-rich Massive Formation. Using data from 25 wells and 36 samples/thin sections, this study focuses on the nature and distribution of porosity in the main Souedih reservoir. The Massive A reservoir is 100–120 m thick and represented by uniform, bioturbated bioclastic packstone and bioclastic packstone-grainstone, deposited in a well-oxygenated, moderate to high-energy, shallow-marine environment. It is generally well cemented by microsparite and micrite, and more rarely by sparite. Porosity is highly variable, ranging from < 1% to 20%. Mouldic porosity is the most common type, with rare channel and fracture porosity. Average porosity values tend to decrease eastward across the reservoir, which can also be divided vertically into five zones. The uppermost of these shows the highest average porosity > 15%. The dominance of mouldic porosity throughout the study area indicates that secondary dissolution was the primary cause and that pre-existing bioclasts were the principal targets for this dissolution. The source of these diagenetic fluids is still unclear, although our data do lend some support to the karstification theory. These characteristics are important for understanding and managing reservoir production, not only for Souedih but for the region in general.

### INTRODUCTION

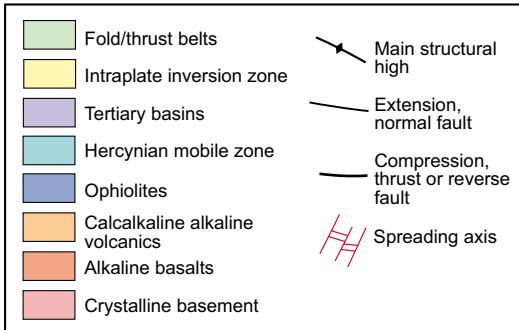
Syria occupies a key tectonic position at the northern tip of the Arabian Plate. It forms the apex of a structural triangle between the Zagros Fold Thrust Belt (ZFTB) and the Dead Sea Fault-Bitlis Fault system (Figure 1). The extreme northeast of the country lies within the northwestern Mesopotamian Basin, in which are located most of the main oil fields of Syria. The traps are mainly structural in nature and the oilfields located at the crests of the principal anticlinal structures; for example: Souedih, Rumailan, **Ulayyan**, and Mashouk anticlines (Figure 1). These are separated from the Sinjar-Abed el Aziz area by deep reverse faults. This whole region is part of the ZFTB that extends southeastwards into the very prolific oil province of Iraq and Iran. The structural and stratigraphic setting has close similarities along the length of the ZFTB.

The Souedih Anticline contains Syria's largest oil field, known as Souedih Field. It extends approximately 25 km west-northwest to east-southeast, reaching a maximum width of about 12 km. The field extends eastwards across the Iraqi border, where it becomes known as the Saffia Field, but the main part of the structure (ca. 18 x 12 km) is located within Syria. The field is situated about 15 km to the south of the **Karatchok Field**, and extends westward towards the Rumailan Field, separated from both by important faults.

The principal reservoir of most fields in the Syrian Mesopotamian Basin is the Upper Cretaceous, carbonate-rich, Massive Formation. However, although these are amongst the largest oilfields and some of the earliest discoveries in Syria, there has been very little detailed work on the region in general, and little published on petrophysical and reservoir characteristics of the Massive reservoirs. The region remains highly prospective, with ongoing exploration and discoveries successfully targeting the Massive Formation.



**Figure 1: Generalised tectonic map of the Arabian platform (Konert et al., 2001). The Souedih Oilfield is located at 37°N and 42°E.**



The aims of this research, therefore, are to (1) document the sediment features and reservoir characteristics; (2) evaluate the vertical and lateral distribution of porosity; and (3) consider primary sedimentary and diagenetic controls on porosity in the Massive Formation of the Souedih Field.

## PREVIOUS WORK

Since 1966 the geology of northeastern Syria has been discussed in a minor way by various authors, including Ponikarov (1966), Lovelock (1984), Leonov et al. (1986), Sawaf et al. (1993), and Brew et al. (1997, 2000). Sharland et al. (2001) provide a broad regional framework through their Arabian Plate sequence-stratigraphic interpretation, with the Massive Formation straddling their AP8 and AP9 mega-sequences. More detailed and focused studies on the tectonic and geological evolution of Syria, including its northeastern part, are found in the works of Kent and Hickman (1997) and Brew et al. (1999, 2001). These works mainly concentrated on the Abd el Aziz-Sinjar area, and gave very little attention to the Syrian part of the Mesopotamian Basin.

Regional geology and relevant petroleum resources are discussed by Beydoun (1988). Metwalli et al. (1974) studied the petroleum-bearing formations in northeastern Syria and northern Iraq; in their study they examined the stratigraphic and depositional development of those areas. Ghabra (1991) studied the source rock formations in the Syrian part of the Euphrates and Mesopotamian basins (east and northeast). The geological control on the distribution of the source rocks and reservoirs in the Upper Cretaceous carbonate of the Adiyaman area (southeast Turkey) was studied by Wagner and Pehlivan (1987); their study included the Mardin Carbonates group (Albian–lower Campanian), which is equivalent to the Massive Formation in Syria.

Unpublished data and reports held by the Gulfsands and Syrian Petroleum Companies (SPC) include two further important but unpublished studies (which the authors have viewed with the kind permission of the companies concerned). These data include: (1) an integrated reservoir engineering study of the Souedih Field, undertaken by IPR International Ltd. in 1996 and further updated in 2003. In their study, a porosity model was built according to the wells drilled up to that time, and the main reservoir unit (Massive A) was divided vertically according to the porosity into three different zones. (2) A sequence-stratigraphic study and correlation of the mid-to-late Cretaceous section of Block 26 in eastern Syria was undertaken by Gutteridge et al. (2009). It includes a study of rock cores and thin sections from Souedih Well 500, and from other chosen wells from some of the oil fields in the Syrian part of the Mesopotamian Basin. Additional private company reports are known to exist, but are not available to the authors.

Recent petroleum-related activity in the region includes exploration and production programmes within Block 26. Discoveries within the Massive Formation include the Khurbet East Field, which came online in 2008, and the Yousefieh Field, which commenced production in 2010. Further activity is expected within the region.

## STRATIGRAPHIC CONTEXT

On the basis of this previous work, we can make the following stratigraphic summary. It is worth noting, however, that the generalized stratigraphic column published in the literature (e.g. Brew et al., 1997, 1999) is representative of eastern Syria, and the Abd el Aziz-Sinjar area, but not necessarily the Syrian part of the Mesopotamian Basin.

The surface topography in northeast Syria is relatively flat-lying with a mean elevation of around 450 m. Recent to Pliocene continental sediments occur at the surface overlying a mainly shallow-marine Tertiary succession. The total thickness of this cover above the top of the reservoir formations encountered in wells is about 900 to 1,100 m, with a maximum of just over 1,300 m in places. The estimated depth to economic basement is approximately 6,000 m (Figure 2, Table 1).

The thick Mesozoic series are dominated by carbonate rocks – limestone and dolomite, which are more-or-less argillaceous. Anhydrite and shale become more common in the Triassic. The Massive

Age	Formation	Depth (m)	Lithology	
Pleistocene	Bakthiary		Silty, sandy, and pebbly clay	
Pliocene	Upper Fars		Sandstone alternating with clay, argillaceous	
Miocene	Lower Fars		Clay interbedded with micaceous, limestone and anhydrite	
	Jeribeh	856	Limestone and clay, dolomite, argillaceous	
Eocene	Midyat	975	Dolomite, dolomitised limestone with intercalation of anhydrite and gypsum	
	Jaddala	1,320	Argillaceous limestone intercalation of dolomite and anhydrite	
Paleocene	Kermav	1,700	Chalky and clayey limestone, marl, beds of clay	
Upper Cretaceous	Shiranish	1,713	Grey and brown argillaceous limestone, thin beds of chalk and clay	
	Massive	A	1,885	Limestone, sometimes slightly argillaceous
		B		Limestone with thin beds of dolomite, increasing with depth and some thin beds of anhydrite
		C		Dolomite with thin beds of limestone and anhydrite
Lower Cretaceous	Ghouna	2,206	Argillaceous dolomite, beds of shale, sandy dolomite	
Middle Jurassic	Qamchouqa	2,245	Argillaceous dolomite, intercalation of limestone	
Upper Triassic	Serjelo	2,373	Alternation of dolomite, shale, and anhydrite	
	Allan	2,670	Anhydrite, dolomite	
	Muss	2,696	Dolomite	
	Adaya	2,743	Limestone, dolomite, intercalation of anhydrite	
	Butmah	2,834	Dolomite, thin beds of shale	
	Kurachine Anhydrite	3,000	Dolomite, anhydrite, thin beds of shale	
Middle Triassic	Kurachine Dolomite	3,062	Dolomite, intercalation of anhydrite, shale, limestone	
Permian	Amanous Sand	3,448	Silty sand, intercalation of shale, and dolomite	
Carboniferous	Marqada	3,750	Silty sand, thin beds of shale, and dolomite	
Silurian	Tanf	4,775-5,110	Alternation of shale and silty sand	

Figure 2: General stratigraphy, lithology and formation thicknesses for the Souedih Oilfield, northeast Syria. Formation thicknesses from Well 1100.

Formation (Albian–Lower Campanian) consists entirely of carbonate rocks and is considered the main productive formation in the region in general, and in the Souedih Field in particular. It is unconformably overlain by the Shiranish Formation (Upper Campanian–Maastrichtian), and unconformably overlies the Rutbah (Barremian–Aptian) or Qamchouqa (Middle Jurassic) formations.

There is some debate over the nature of events that affected the region following deposition of the Massive Formation. According to Gutteridge et al. (2009) uplift during the end-Santonian tectonic phase resulted in exposure and karstification before the later westward transgression phases during the Campanian–Maastrichtian, which finally resulted in the burial of the previously exposed sediments under the marl and clayey carbonate rock of the Shiranish Formation (Upper Campanian–Maastrichtian). The engineering study of the Souedih Field (IPR International Ltd., 2001) also suggests the existence of karsts but without giving any evidence. However, other authors who have undertaken studies in the same area think that there is insufficient evidence to infer the existence of karsts on the top of the Massive Formation (e.g. A.K. Al-Maleh, personal communication, June 2010).

Jassim and Goff (2006), in writing about the equivalent series in northwestern Iraq, make no mention whatsoever of any uplift or karstification in their mega-sequence AP9, which extends from Late

Turonian into Danian. Meanwhile, Wagner and Pehlivan (1987) refer to the existence of an erosional surface at the top of the Karababa-C carbonate unit in the Adiyaman area of southeast Turkey that shows leached porosity created during a short period of exposure. The Karababa-C is considered one of the main reservoirs in southeast Turkey and may be equivalent to the upper part of the Massive A member (Coniacian–Lower Campanian).

## DATABASE AND METHODOLOGY

The data used in this study consists of exploratory well information, including porosity logs from 25 wells located on the different parts of the structure (Figure 3), 36 selected rock samples from cores in two chosen wells, a top Massive isopach map on the Souedih structure, and top formation data from about 100 wells. These data are all used with the permission of SPC. The database also includes tectonic and geologic maps of Syria, and both published and unpublished literature from previous studies of northeastern Syria.

These data were analysed and used to construct a model of the Massive A Member (Figure 3) in Schlumberger's Petrel software. Previously calculated porosity logs (provided by SPC) were digitized, and the Massive A was divided into several porosity-derived zones which were then correlated across the dataset. Specific porosity maps were constructed for each zone.

Additionally, cores and selected core samples were initially described in hand specimen, and then in thin section.

## RESULTS

### Massive Formation

The Massive Formation can be divided informally into three members from top to base as follows (Table 1). *Massive A* (Coniacian–Lower Campanian) is, as its name implies, a relatively massive (i.e. thick to very thick-bedded and structureless in aspect) limestone unit, which is only slightly argillaceous in places. *Massive B* (Upper Cenomanian–Turonian) is a limestone unit with thin beds of dolomite, increasing in frequency downwards, and less commonly with thin beds of anhydrite. *Massive C* (Albian–Lower Cenomanian) is mainly dolomite, with thin beds of limestone and anhydrite. With reference to Sharland et al.'s (2001) Arabian Plate sequence stratigraphic framework, the Massive Formation straddles their AP8 and AP9 mega-sequences. It is believed that their K160 and K170 maximum flooding surfaces sit within the Massive A Formation, the K140 and K150 within the Massive B Formation and the K90, K100, K110, K120 and K130 within the Massive C Formation.

Oil and gas is mainly produced from the Massive A Member, which has an average thickness of about 100–120 m, varying from over 200 m in some wells to less than 15 m in others. In general, it increases in thickness towards the east. The average depth to the top of the Massive A is about 1,750 m, but ranges from 1,582 m to over 1,900 m subsurface. We have therefore restricted this initial study of porosity and lithology to the Massive A Member.

### Porosity Distribution

Both regional and vertical variations in average porosity values in the Massive A are evident from an examination of the porosity logs from the wells in the study area. On a regional basis, there is a tendency for porosity values to decrease in an eastwardly direction. Porosity would normally be expected to decrease with depth, but in this case appears to show a marked increase (see Figure 3 and Figure 4). In general, average porosity values are higher in the deeper western wells, low in the shallower eastern wells, with a transition region shown in the more central parts of the field.

With reference to three sets of three closely spaced representative wells from each of the western, central transition and eastern areas, mean porosity values were derived. The values of average porosity in the western wells are over 14% (with few exceptions), exceeding 20% in some wells. The

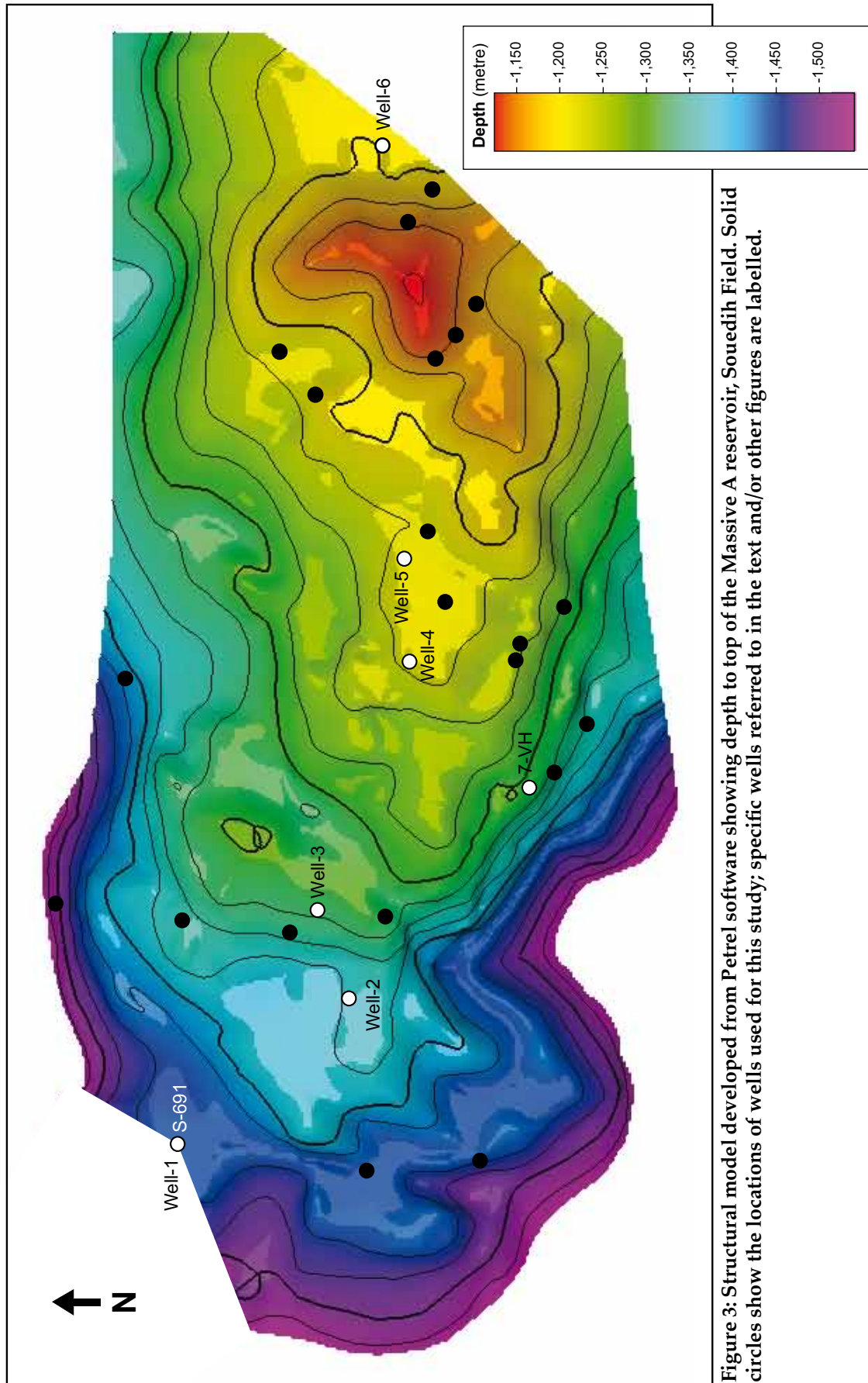


Figure 3: Structural model developed from Petrel software showing depth to top of the Massive A reservoir, Souedih Field. Solid circles show the locations of wells used for this study; specific wells referred to in the text and/or other figures are labelled.

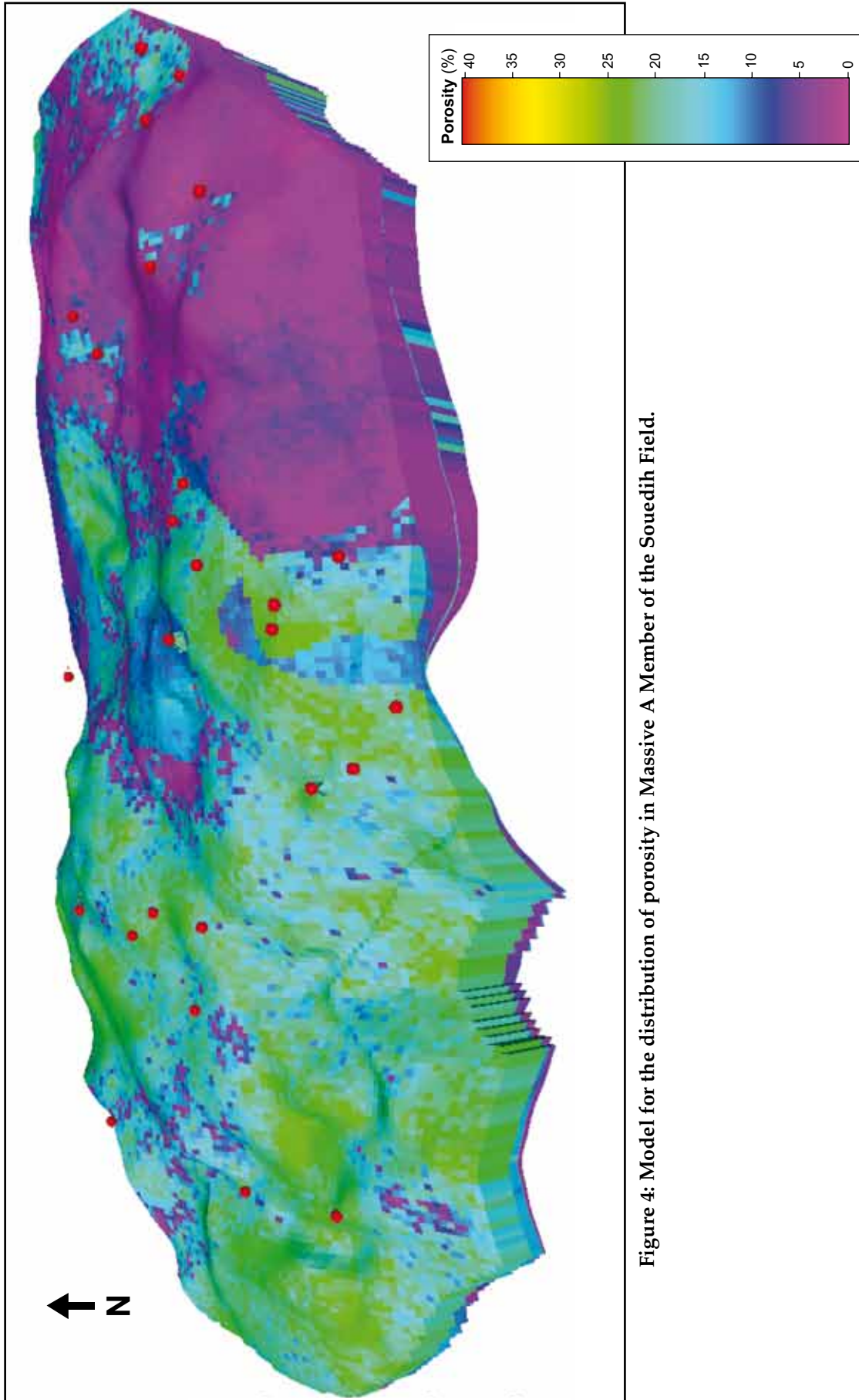


Figure 4: Model for the distribution of porosity in Massive A Member of the Souedih Field.

equivalent values are less than 5% in the eastern wells (with very few exceptions), and they are more variable in the transition region, exceeding 20% in some wells, decreasing to less than 6% in others, and in general they average greater than 10%.

With regard to vertical variation in porosity, we recognise the existence of five zones, which themselves show regional variations in thickness (Figure 5). The regional model for the distribution of porosity is constructed for each zone and shown in Figure 6. The Massive A porosity zones are, from top to base:

*Zone A1* extends between the top measured horizon (which generally corresponds with the top of the Massive A, or a few meters beneath it) and horizon 1. This zone is characterized by porosity values generally equal to or more than 15%. It mainly exists in the western area (where it may extend downward to the base horizon) and in the transitional region. It generally thins towards the east and is totally absent in the extreme east of the field. In some wells, Zone A1 contains thin intervals in which the porosity values are less than 8%; these have their minimum thickness and frequency in the western parts of the field.

*Zone A2* extends between horizon 1 and 2. It has an average porosity value of about 10–12% but, like Zone A1, it contains thin intervals in which porosity values may be less than 6%. Zone A2 extends in some western wells from horizon 1 to the base horizon, but it has its maximum thickness in the transition region, where it exceeds 60 m in Well 411.

*Zone A3* extends between horizons 2 and 3, with average porosity less than 6%. Its thickness varies widely from minimum values in the western part, where it may be absent in some wells, to maximum values in the eastern part, where it may occupy the whole Massive A in some of the most easterly wells.

*Zone A4* extends between horizons 3 and 4, with average porosity values mostly in excess of 10%. However, it has some thin intervals (2–4 m thick), in which porosity values exceed 20%, and other intervals with values less than 5%. This zone is absent in most of the western and extreme eastern wells, but its thickness may exceed 40 m in some of the transition region wells (e.g. wells 2VH and 690).

*Zone A5* extends between horizon 4 and the base of the Massive A, with average porosity values less than 5%. It is absent, or very thin (less than 2 m), from the entire western and most of the transition area wells, while its thickness may reach about 100 m in the eastern wells.

### Sediment Facies and Microfacies

A total of 36 rock specimens and thin sections were selected from the available cores in two wells (Figures 3 and 7): (1) Well S691 located in the western part of the field (450 m kelly bushing elevation, and depth interval of Massive A is 1,886–1,980 m). (2) Well S2VH located in the transition region (489 m kelly bushing elevation, and depth interval of Massive A is 1,775–1,917 m). The samples from both wells were taken from Zone A1, which has the maximum average porosity, and from Zone A3, in which the average porosity value is one of the lowest.

In hand specimen the sediments are uniformly grey brown in colour, with an apparently fine-grained groundmass and variably abundant bioclasts. Many of these appear as remnant ghosts that have been more-or-less replaced by microsparitic to micritic cement. There is no evidence of lamination or other primary sedimentary structures. Bioturbation appears common, though indistinct, while burrow traces are rare.

In thin section, the composition and classification of all the samples are very similar to each other (Figures 8 and 9): *bioclastic packstone* and *packstone-grainstone* in S691, and *bioclastic packstone* in S2VH. The dominant bioclasts consist mainly of bivalves (shallow water types), molluscs, echinoderm plates, benthic foraminiferans (particularly orbitoids and miliolinids), and ostracods. In some thin sections we observe planktonic foraminiferans inside benthic species. The bioclasts appear abraded, and moderately to well sorted. Most samples contain some large, dispersed, cloudy crystals of diagenetic

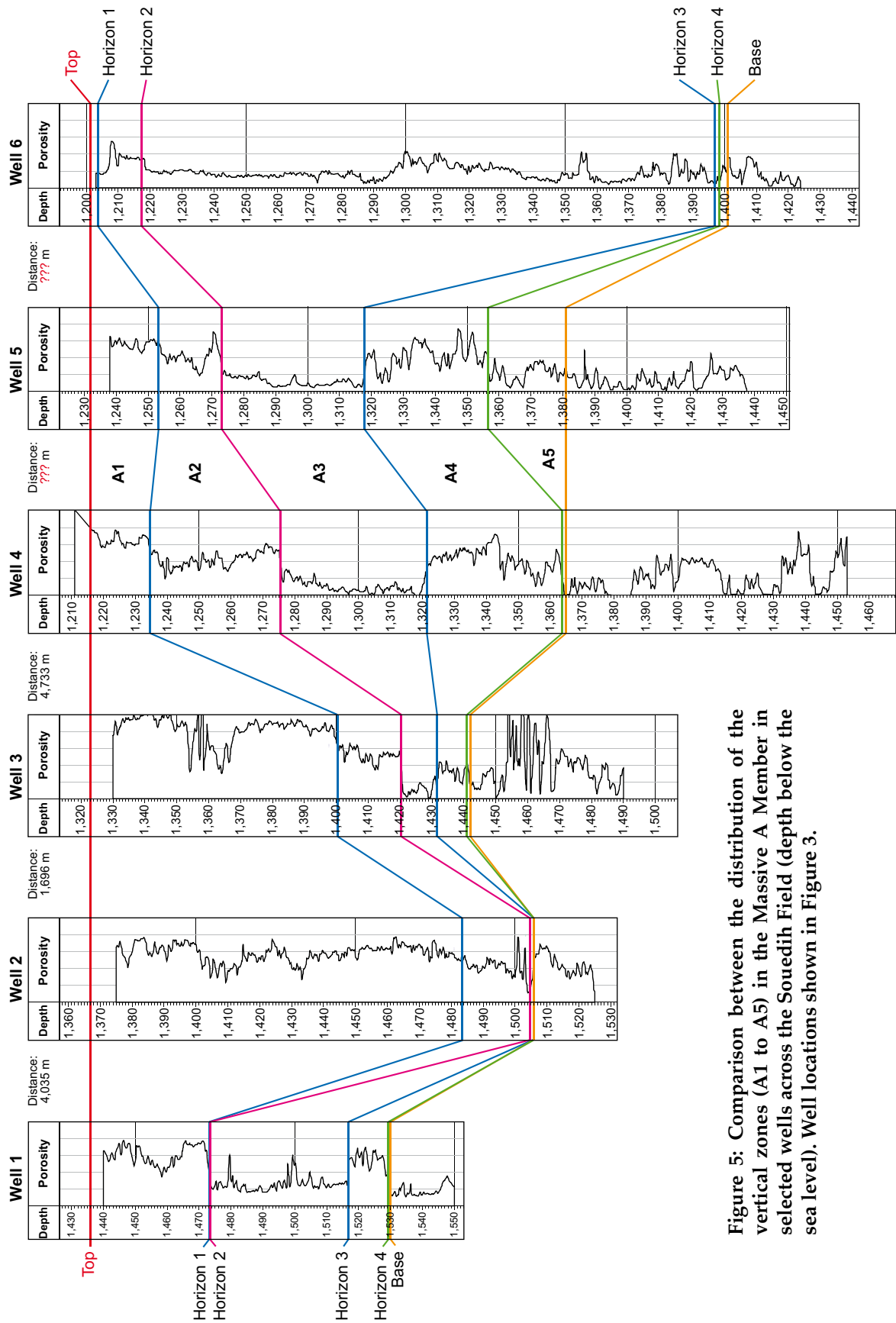
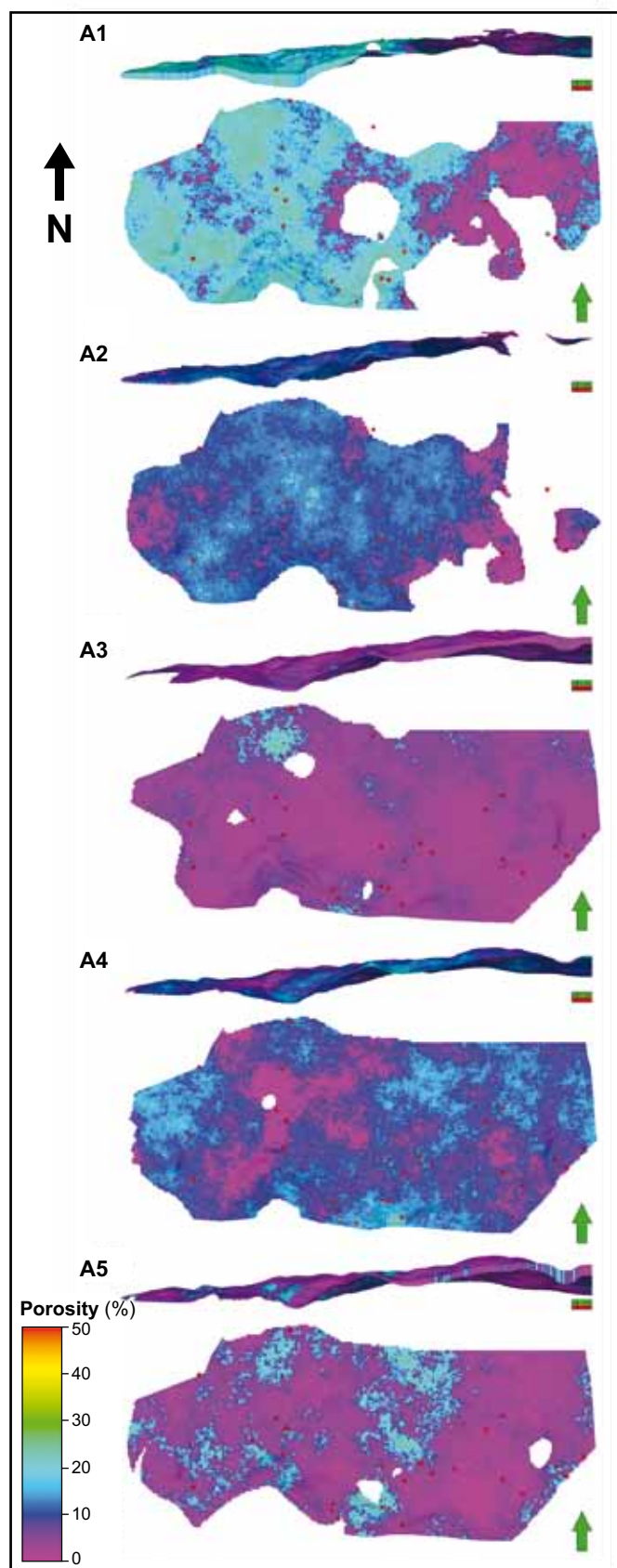


Figure 5: Comparison between the distribution of the vertical zones (A1 to A5) in the Massive A Member in selected wells across the Souedih Field (depth below the sea level). Well locations shown in Figure 3.



**Figure 6:** Petrel-derived models showing the distribution of the porosity in zones A1 to A5 of the Massive A Member, Souedih Field. Note the changing of the thickness in each zone across the area.

dolomite (not exceeding 10–20%). Other mineral grains encountered in some thin sections are small scattered pyrite crystals, greenish-coloured glauconite grains, and small fragments of phosphate and chert. In some samples there are bitumen spots and impregnations.

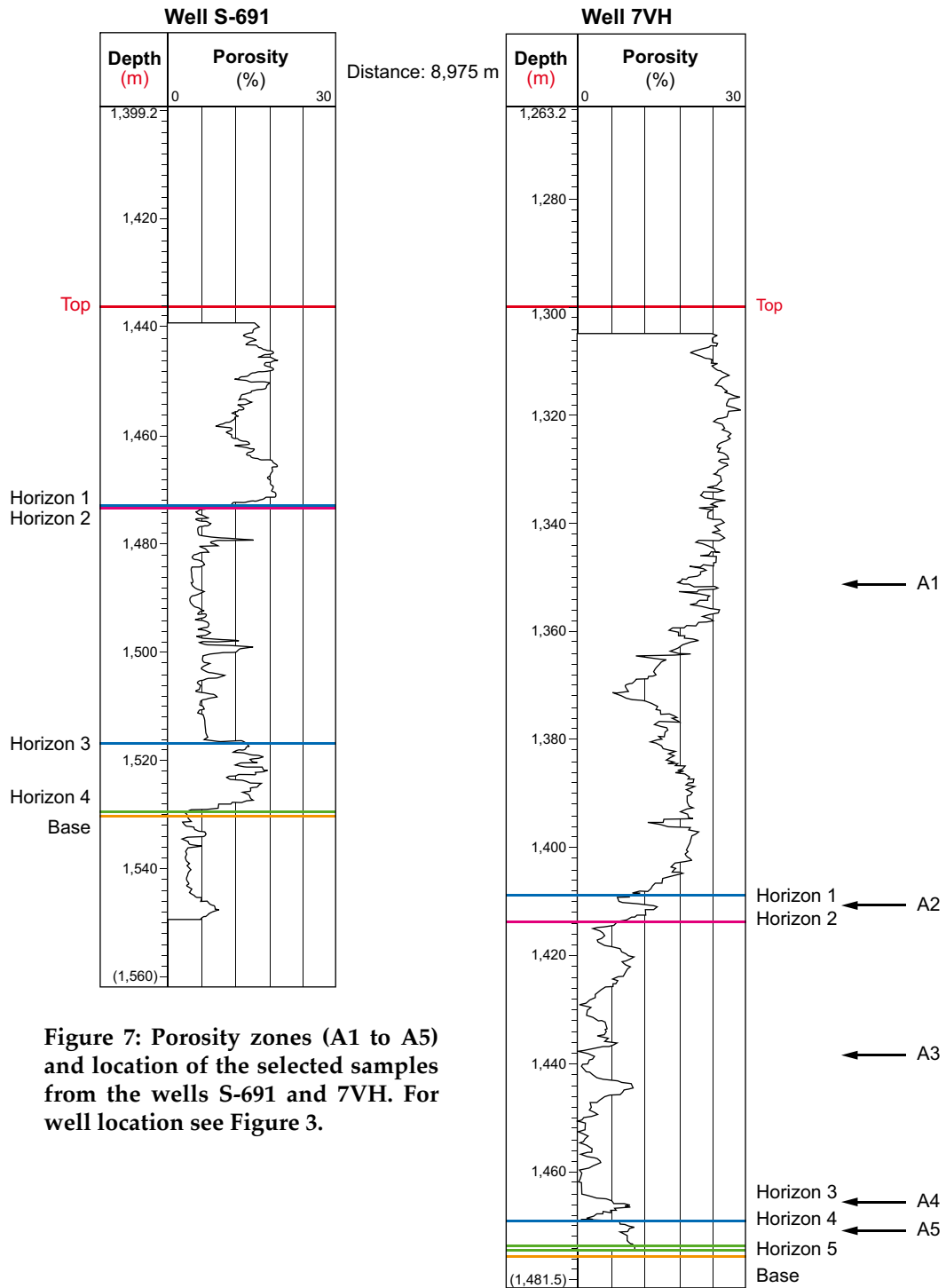
The principal cement is microsparite or micrite and microsparite, with at least two generations evident. Larger sparite cement is found locally, partially or wholly filling mouldic pore spaces or channel spaces. Early micritisation of the walls of the bioclasts has helped them to resist the effect of compaction, but the effect of the later dissolution, cementation and partial dolomitisation, has made them difficult to distinguish clearly. They commonly appear in some thin sections as remnant ghosts.

By far the dominant and in many cases the only porosity observed is mouldic porosity, from both zones (A1 and A3) (Figure 9). In a few samples there is also some channel porosity and micro-fracture porosity. Overall the relative abundance and size of the mouldic pore spaces in the thin sections taken from Zone A1 are clearly greater than those taken from Zone A3. It is possible that the increased amount of sparitic cement in certain parts, for example Zone A3, have infilled pre-existing mouldic porosity. However, the alternative interpretation that the sparite came first and has not been fully removed by secondary dissolution cannot be ruled out. Further work is required.

## DISCUSSION

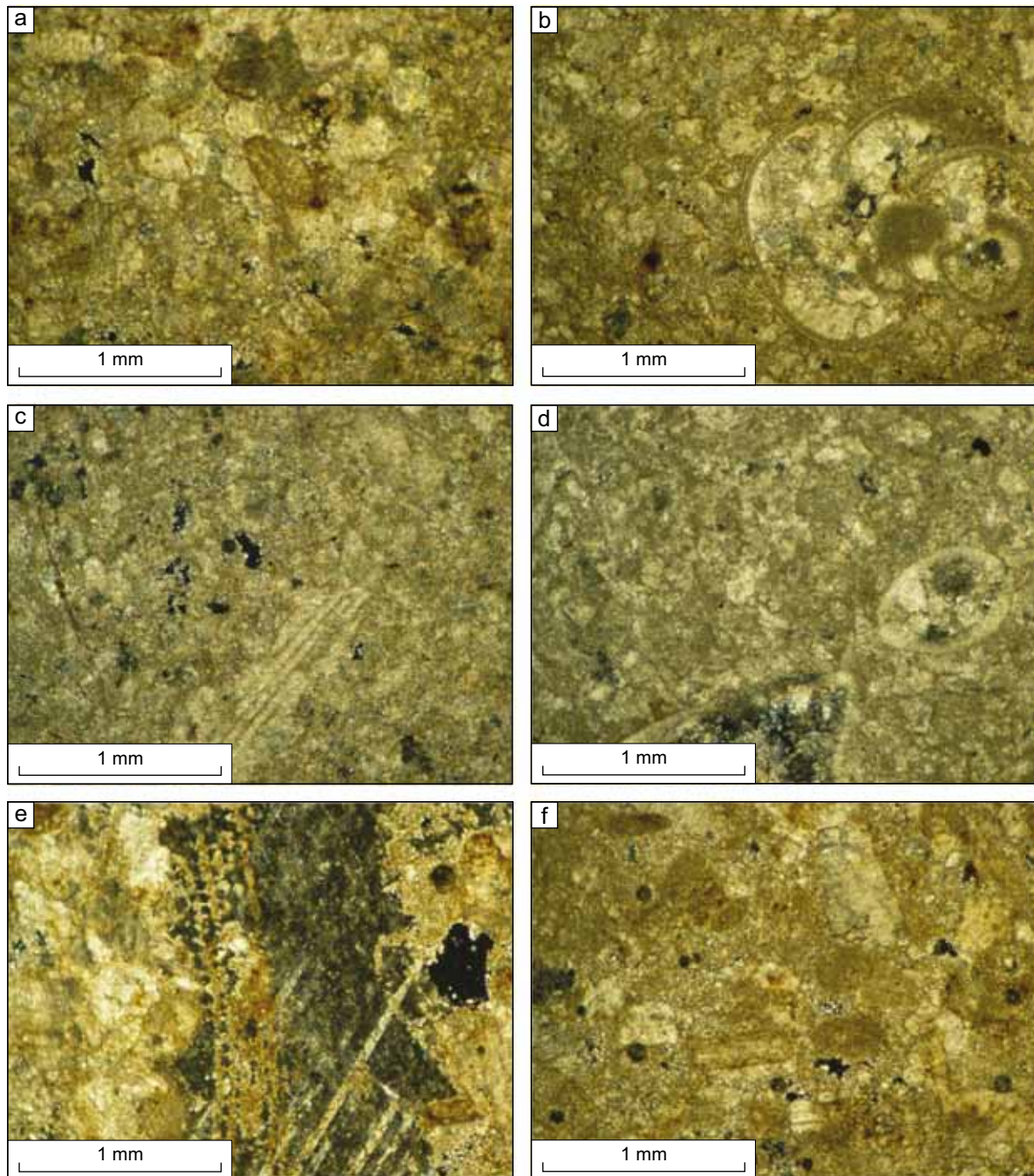
### Depositional Environment

Based on our general observation of the cored sections in all wells studied, as well as the details of facies and microfacies presented above, we can suggest that the sedimentation took place in shallow marine water, in a moderate to high energy, well-oxygenated environment. Bioclasts are abundant and abraded, but true bioclastic grainstones are rare; extensive bioturbation has destroyed any vestige of primary sedimentary structures. Deposition most likely occurred at or just above normal wave base.



**Figure 7: Porosity zones (A1 to A5) and location of the selected samples from the wells S-691 and 7VH. For well location see Figure 3.**

These observations are in line with previous work on neighbouring areas (Gutteridge et al., 2009) and with in-house lithological and stratigraphic studies presented in individual well reports by the Syrian Petroleum Company. These infer that, during deposition of the Massive Formation, the paleo-shoreline lay some distance to the west, while the open sea was to the east. Deposition took place on a shallow shelf that increased in depth eastwards. For the part of the Mesopotamian Basin in northwestern Iraq close to the Syrian border, Jassim and Goff (2006) mention that sedimentary environments in the Late Turonian to Early Campanian ranged between deep inner shelf and lagoonal.



**Figure 8:** Photomicrographs of thin sections to show characteristic microfacies types. Note that mouldic porosity is well-developed in some samples and absent in others.

(a) Bioclastic Grainstone: the bioclasts consist mainly of benthic foraminifera (note the Orbitoids near the centre of the photo). Well S-691; depth interval 1,900–1,901 m.

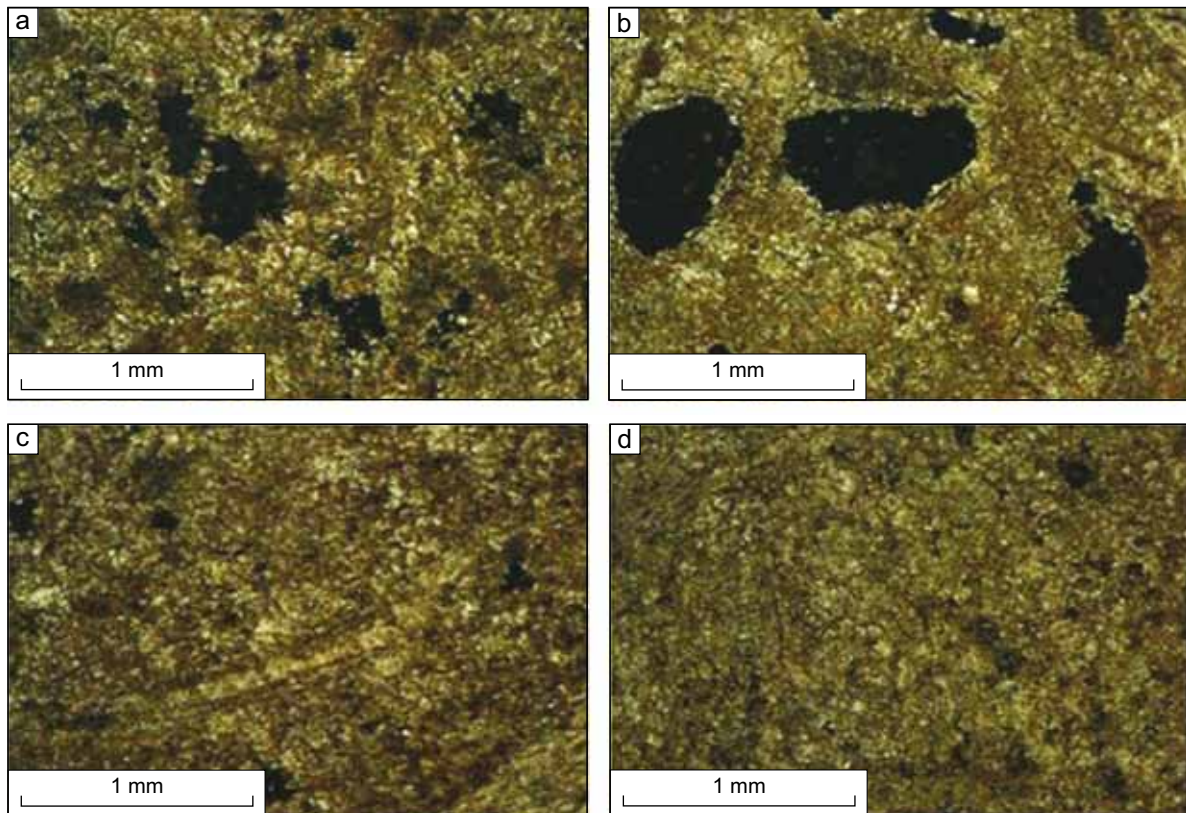
(b) Bioclastic Packstone-Grainstone: the bioclasts consist mainly of benthic foraminifera. Well S-691; depth interval 1,902–1,903 m.

(c) Bioclastic Packstone: bioclast ghosts plus clear longitudinal section through echinoid spine. Well S-691; depth 1,905 m.

(d) Bioclastic Packstone; bioclasts include ostracod (right) and bivalve fragment (bottom). Well S-691, depth 1,907 m.

(e) Bioclastic Packstone; bioclasts include rudist fragments. Well 7VH; depth 1,850 m.

(f) Bioclastic Packstone, partially dolomitised: the dominated bioclasts include benthic foraminifera (mainly Orbitoids), plates of echinoderms and fragments of bivalves. Well 7VH; depth 1,846 m.



**Figure 9: Representative photomicrographs of the microfacies and dominant porosity type (mouldic). Thin sections taken from Zone A1 and Zone A3 of wells S-691 and 7VH.**

- (a) Zone A1; high porosity. Thin section from Well S-691; depth 1,452 m.
- (b) Zone A1; high porosity. Thin section from Well 7VH; depth 1,343 m.
- (c) Zone A3; low porosity. Thin section from Well S-691; depth 1,481 m.
- (d) Zone A3; low porosity. Thin section from Well 7VH; depth 1,416 m.

### Controls on Porosity

The complete dominance of mouldic porosity throughout the study area clearly indicates that secondary (diagenetic) dissolution was the primary cause and that pre-existing bioclasts were the principal targets for this dissolution.

The relative abundance of bioclasts across the region, therefore, would have exerted an important control on porosity development and its distribution. That porosity is higher in the west may well have been a function of greater numbers of bioclasts in the relatively shallower waters of this area. The transition zone probably displayed a more patchy distribution of bioclasts and hence a more variable porosity distribution. The vertical zonation of porosity we observe in the Massive A Member might further reflect a shallowing upward trend, at least in part, with increasing bioclasts and hence increased porosity upwards to our Zone A1.

The nature, source and volume of fluids responsible for the dissolution are equally important controls on porosity development. Both the domination of dissolution porosity and its preferred occurrence in the uppermost parts of the Massive A may be considered as evidence in support of the existence of regional uplift and karstification sometime following final deposition of this formation. This would have led to an influx of aggressive freshwater from the top downwards. A karstic horizon and unconformity above the Massive Formation has been invoked for other reasons by previous studies (e.g. Gutteridge et al., 2009).

However, the evidence to date is still preliminary and not yet conclusive in our opinion. Other sources of dissolving fluids must also be considered, such as formation fluids that were weakly acidic, with organic acids as precursors to hydrocarbon migration into the reservoir. The timing and pathway for such fluid influx needs further work.

Furthermore, the presence and distribution of micro-porosity across the field is unknown at present. However, from the evidence available to us, we believe that overall the influence of micro-porosity is likely to be low. Whilst porosity curves can be susceptible to micro-porosity, the available core analysis porosity data is consistent with calculated porosity logs. Also, calculated log porosity from available rock samples and thin sections was very low where there was no mouldic or channel porosity. Whilst from a very small localised sample, this may be indicative of a low level of influence of micro-porosity elsewhere within the Massive A Member.

## CONCLUSIONS

The Massive A Member of the Massive Formation is the main reservoir in the Souedih Field; it consists almost entirely of carbonate rocks with an average thickness of ca. 100–120 m. The reservoir facies are represented by uniform, bioturbated bioclastic packstone and bioclastic packstone-grainstone, cemented mainly by microsparite and micrite. Porosity is highly variable, ranging from < 1% to ca. 20%. Mouldic porosity is the dominant type, with rare channel and fracture porosity. Where mouldic porosity is abundant there are high average porosity values, and where there is little mouldic porosity, average values are low. In places, sparitic cementation infills the pre-formed mouldic porosity or channels and microfractures, and so plays a role in decreasing the porosity values in some sections.

There are some clear trends in both vertical and lateral distribution of porosity across the reservoir. Within the Massive A Member, porosity values are highest in the west, variable and intermediate in a central transition region, and lowest in the east. Vertically, five different porosity zones are recognised (A1–A5), in general showing highest porosity in the upper zone.

Lateral trends are thought to be associated with regional water depth at the time of deposition, whilst vertical zonation may relate to a shallowing upward trend. Overall, the associated distribution of bioclasts, and their preferential dissolution, is believed to be the dominant control on porosity. The impact of subsequent uplift, karstification and the influx of aggressive freshwater is recognised as the preferred mechanism for dissolution.

Reservoir quality across the Souedih Field is observed to be highly variable. In some instances, early micritisation may have preserved porosity by reducing the impact of compaction. Elsewhere, highly heterogeneous intervals, with either high or low average porosity, in comparison to the rest of the zone, are apparent.

Whilst this study has concentrated on one field, clearly these characteristics and their observed variation within the Souedih Field are important for understanding and managing reservoir production, not only for Souedih but for the region in general. However, we would emphasise again that this is a preliminary study based on limited data and that further work is essential to validate and refine our findings.

## FURTHER WORK

The next phase of research in this area should be a much broader-based regional study of the principal late Cretaceous reservoir formation, involving multiple wells and multiple fields. This would build upon our own detailed work and seek to incorporate this into a more complete regional sequence-stratigraphic framework, similar to that proposed locally by Gutteridge et al. (2009). Specific targets might include: (1) careful study of the top Massive A boundary, in order to ascertain the nature of the inferred unconformity and evidence for the existence or absence of a karstic horizon; (2) geochemical studies in order to determine likely fluid types and timings causing the secondary dissolution; (3) a regional investigation of our observed porosity zones in order to better understand their cause and likely effects; and (4) assimilation of additional available geological data as it becomes available.

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