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Sequence Stratigraphic and Diagenetic alterations within the Silisiclatic Reservoir Deposits of Orange Basin, Southwestern Africa Margin.

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ABSTRACT

The Orange Basin in South Africa of South Atlantic Ocean consistently has shown poor reservoir quality. The reservoir been a silisiclastic deposit normally should have shown good to very good quality. The poor porosity and permeability characteristics of the reservoir across the five blocks in the basin necessitated this work. In finding the cause of the problems in the basin, some wells were subjected to sequence stratigraphic and diagenetic analyses. This was done using the digital wireline logs and 2D seismic sections, sidewall core and core samples acquired form Petroleum Agency of South Africa (PASA). The wireline logs were interpreted and broken to parasequence sets. The seismic section also interpreted based on unconformities, reflection truncations and terminations to obtain sequence stratigraphic framework. Core and sidewall core samples were collected within parasequence settings: Highstand HST, Lowstand LST and Transgressive system tracts to look at the effect of diagenetic alterations within the framework. The cores samples were subjected to: Thin sectioning, XRD, SEM, and EDS analyses to reveal the deposition and post deposition history of the basin. It was shown that authigenic minerals and quartz over growth is responsible for the poor reservoir quality of the reservoirs.

Key words: Sequence stratigraphy, Diagenesis, Wireline logs, Siliciclastic, authigenic

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INTRODUCTION

The continental margin around South Africa's coastline is approximately 400 000 km^2, it comprises of 165 000 km^2 of continental shelf (Broad et al, 2006). A greater part of the Orange basin is encompassed by the western continental margin of South Africa (Fig 1), which is passive volcanic margin (Jungslager, 1999) that covers an area of 145 000 km^2 (Broad et al., 2006). Aggradation during the late Cretaceous led to a collapse of the shelf edge, during early Cenozoic, in the form of extensional growth-faults, large-scale slumping and associated compressional thrusting occurred (Broad et al, 2006). This succession is characterized by organic and chemical sedimentation with relatively little terrigenous/siliclastic input (Broad et al, 2006). The terrigenous/siliclastic input in this basin shows very poor quality in terms of porosity and permeability.

The need to know how diagenesis, detrital composition and depositional environment influence the reservoir quality of sandstone is gaining it relevance in petroleum geology. It has been shown that there is a diagenetic alteration related to sequence boundaries which includes mechanical clay infilteration and formation which may affect the reservoir properties in a basin. Silisiclastic reservoirs are known to be good reservoirs because they often have high porosity and permeability. The reverse is the case in wells in Orange basin (Macdonald et al., 2003). The problem of reservoir in the Orange Basin might be as a result of clay infilteration and formation which can be studied by integrating sequence stratigraphy with diagenesis.

Relationship between sequence stratigraphy and diagenesis for carbonates deposits were well documented by Read and Horbury, 1993; Tucker, 1993 and Moss and Tucker, 1995 and not many studies has been done on siliciclastic, hence this research. The paucity of informations and causes of poor quality of the Siliciclastic reservoir is responsible for this research work. Sand deposited below subaerially exposed sequence boundaries may be subjected to percolation of meteoric water, which typically results in dissolution of unstable framework grains (e.g. mica and feldspar) and formation of intergranular porosity and kaolinite. Favourable conditions for the formation of intergranular porosity and kaolinite occur below the unconformities with much longer subaerially exposed time than the sequence boundaries in the sequence stratigraphic sand and humid climates (van Wagoner et al., 1990).

METHOD AND RESULTS

This research was carried out using the digital wireline logs and 2D seismic sections, sidewall core and core samples acquired form Petroleum Agency of South Africa (PASA). The wireline logs were interpreted and broken to parasequence sets. The seismic section was also interpreted based on unconformities, reflection truncations and terminations to obtain sequence stratigraphic framework. Core and sidewall core samples were collected within parasequence settings: Highstand HST, Lowstand LST and Transgressive TST system tracts to look at the effect of diagenetic alterations within the framework. The cores samples were subjected to: Thin section, XRD, SEM, and EDS analyses to reveal the deposition and post deposition history of the basin.

The preliminary investigations for this work were carried out on the digital data set acquired from PASA using specialised software. The zones of interest were marked out for samples core and side wall cores sample acquisition. The samples were subjected to the following analyses: thin section, XRD, SEM and EDS.

Thin section involves samples set in open sample trays with clean glass slides. Sample numbers marked on the glass slide with diamond scriber. Samples number checked against the marked number on the glass slides to ensure the sample identity is correct. Each samples ground to a flat surface using only diamond abrasive either as dry or with distilled water. Sample grinding done by hand on a flat plate for the core samples. Samples that required stabilization (the side wall core samples) prior to grinding, were stabilized using epoxy. The prepared slides were analysed using petrographic microscope. Within LST in well K_B1 at depth 1950m (Fig. 2 A) the mica is flattened or platy which can be as a result of serve compaction and it is embedded within quartz. At the same depth within the well there is presence of glauconite which is shown by green colour in both plane and cross polarised lights. The glauconite is diagnostic of the continental shelf marine depositional environment which might have been formed due to diagenetic alterations of mica under a reducing condition. In TST the micas appear as specs except in A_C2 (3245.16m) (Fig. 3 A), which shows complete alteration and grading. There is a lot of chloritisation within the setting, which may be responsible for the generally low porosity. The well A_O1 at depths 3679m and 3493m (Fig. 4 and 5 respectively) within HST showed lot of clay covering the detrital grains.

The Core and Side wall core samples collected at various stratigraphic settings were analysed by XRD to assess any mineralogical changes. The samples were pulverised. A Bruker D8 advance instrument with a pw3830 x-ray generator operated at 40 kV per 25mA was used and a scan speed of 4° (2 theta) mins. The setting LST results show a good place for understanding of redox environment because of the presence of pyrite and hematite. Pyrite is often believed to be formed under a reducing condition and was found squeezing feldspar between quartz grain clast (Fig. 2B). The XRD results in TST (Fig 3B) show more pyrite meaning that the setting is more reducing than oxidizing. This is supported by low amount of hematite which is found mainly in oxidizing environments. Pyrite formation is an indication of iron-reduction in the setting, an example of eogenetic alteration linked to sequence stratigraphy. The results of XRD show more quartz overgrowth which is likely to be achieved as a result of sea level fall in HST (Figs 4B and 5B). This is buttressed by more hematite which is formed in highly oxidizing environment. The hematite formation must have been exposed to oxidizing condition during the period following burial. This implies exposure of groundwater with high oxidation state ions to atmosphere typical of HST. There is also limited grain coating which is responsible for the abundant quartz in the setting.

The SEM/EDS analyses involve each samples coated with Gold Palladium for about 30 minutes. This was done to make the samples conductive. The coated sample was put on a palette-like stand which was placed under an electron beam. The machine used for the SEM analysis is a LEO Stereoscan 440 which is a high vacuum microscope. A conventional Be window, Si (Li) detector with a 1024 channel MCA set to 10eV per channel was employed for EDS analysis. Picoammeter was attached to measure beam and or specimen current. Samples were metallographically polished to 0.3 micron metre grit to make them conductive. The SEM result within the LST in well K_B1 at depth 1950m (Fig. 2D) shows overgrowth of quartz and chlorite obscuring pore throats. The EDS at same depth shows Cr, Fe and Ni, complete replacement of Si (Fig 2C). There is severe authigenic minerals deposition as shown within TST in well A_C2 at depth 3245.16m Fig (3D), while the EDS shows Al, Si and K (Fig 3C). The HST in well A_O1 at depths 3679m and 3494m shows overgrowth of quartz and authigenic minerals precipitation (Figs 4D and 5D). The EDS result shows Ca, Al, Si, S, K and Fe at depth 3679m and Ca, K, Al, Si Cl, and Fe at depth 3494m (Figs 4C and 5C). The presence of sulphur in A_O1

(3679m) is an indication of reducing condition that will enhance the formation of pyrite

CONCLUSIONS

The Orange Basin shows enormous clay infilteration due to precipitation and flooding events, which is one of the factors responsible for the poor reservoir quality within the basin. Diagenesis of Orange basin sandstone shows evidence of compaction, cementation and replacement of minerals within the stratigraphic sequences. Early diagenesis events include mechanical compaction, pore filling and formation of montmorillonite and chlorite. The late diagenesis includes formation of quartz cement, chlorite, pyrite and hematite. The late diagenetic sandstone and authigenic clay minerals seem to have formed from mainly ions release from clay mineral transformations in the adjacent shales.

The LST setting shows a good place for understanding of redox environment because of the presence of pyrite and hematite. Pyrite is found squeezing feldspar between quartz grain clast in the setting.

Pyrite formation in TST is indicative of iron-reduction in the setting, an example of eogenetic alteration linked to sequence stratigraphy. This is formed as a result of maximum flooding event in the setting. There is relative abundance of chlorite in the setting because it is less extensively coated during late diagenetic events.

The results of XRD show more quartz overgrowth which is likely to be achieved as a result of sea level fall in HST. The hematite formation must have been exposed to oxidizing conditions during the period immediately after burial. This implies exposure of groundwater with high oxidation state ions to atmosphere typical of HST. There is also limited grain coating which is responsible for the abundance quartz in the setting.

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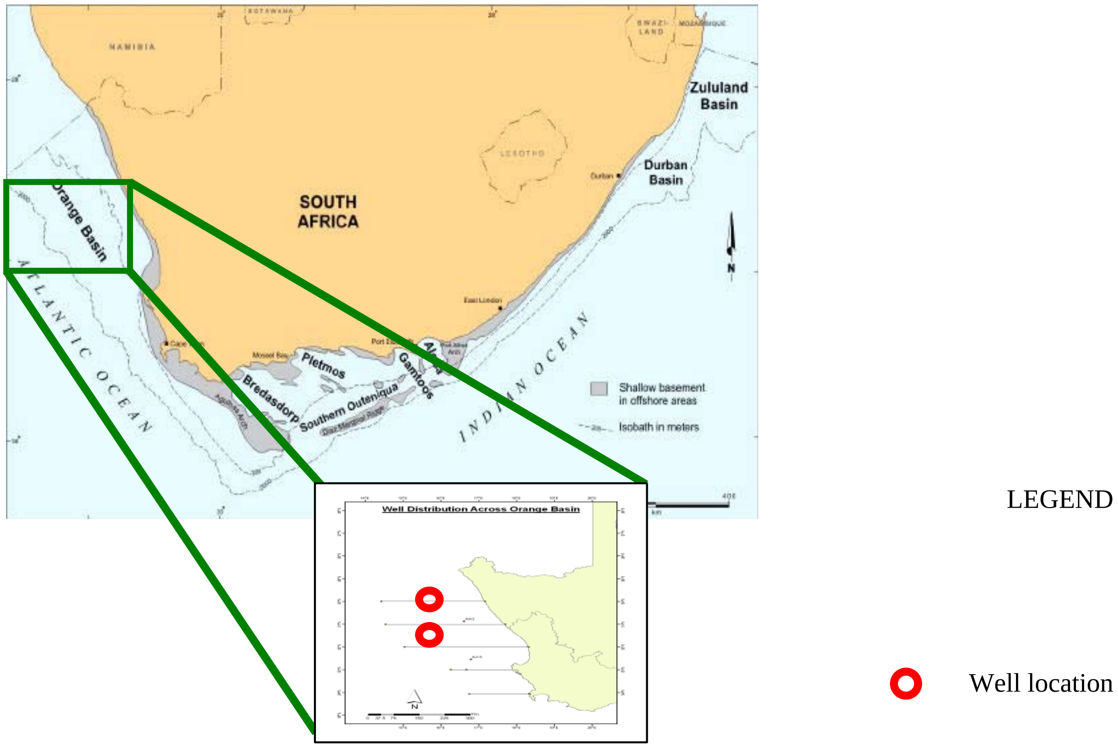

Fig 1. Map of South Africa showing the position of Orange basin and well locations using GIS (Modified from Broad, 2004)

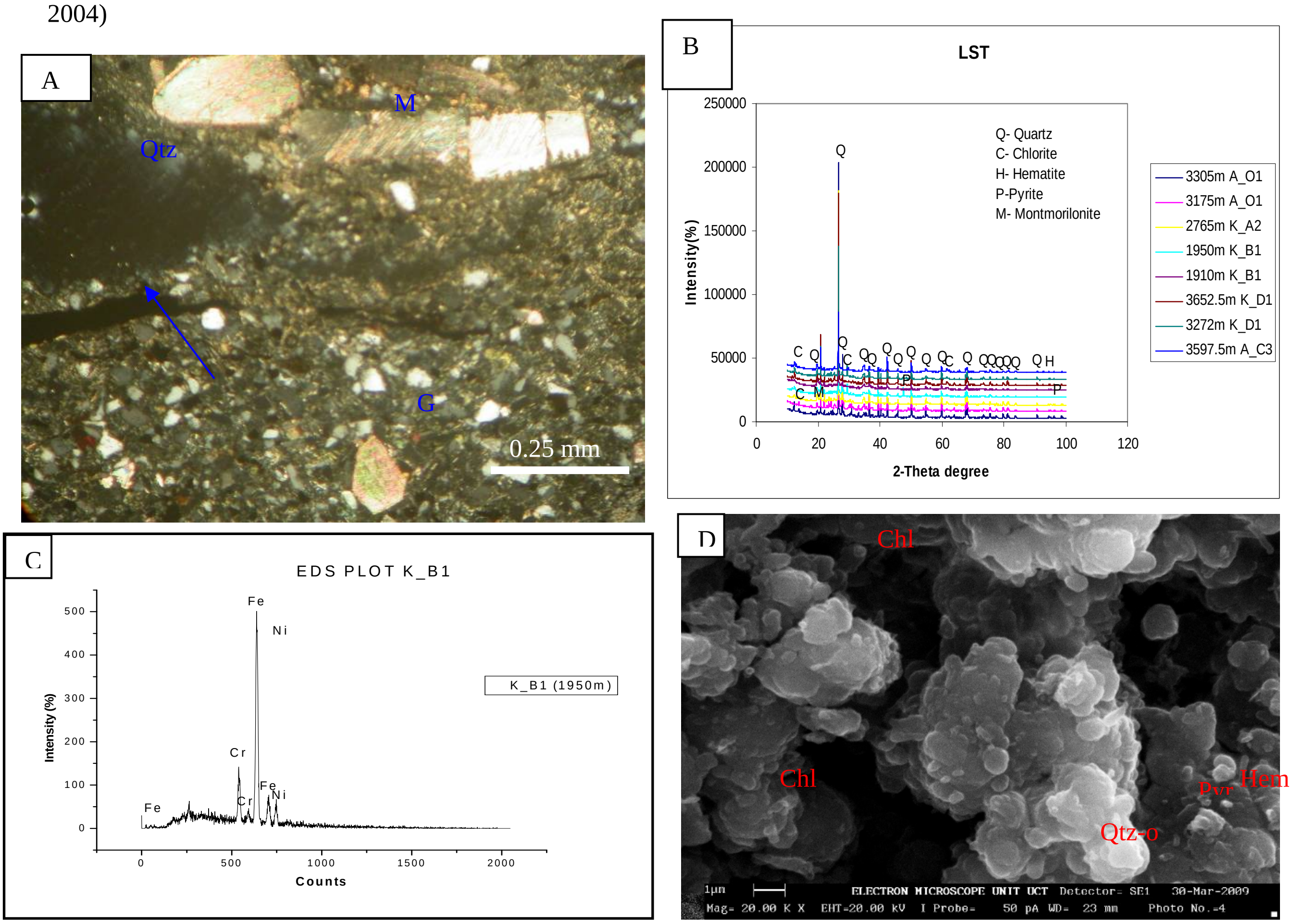

Fig 2 Results of analyses on sample collected within LST in well K_B1 at depth 1950m. (A) Thin section result. (B) The XRD result, (C) EDS result and (D) the SEM result.

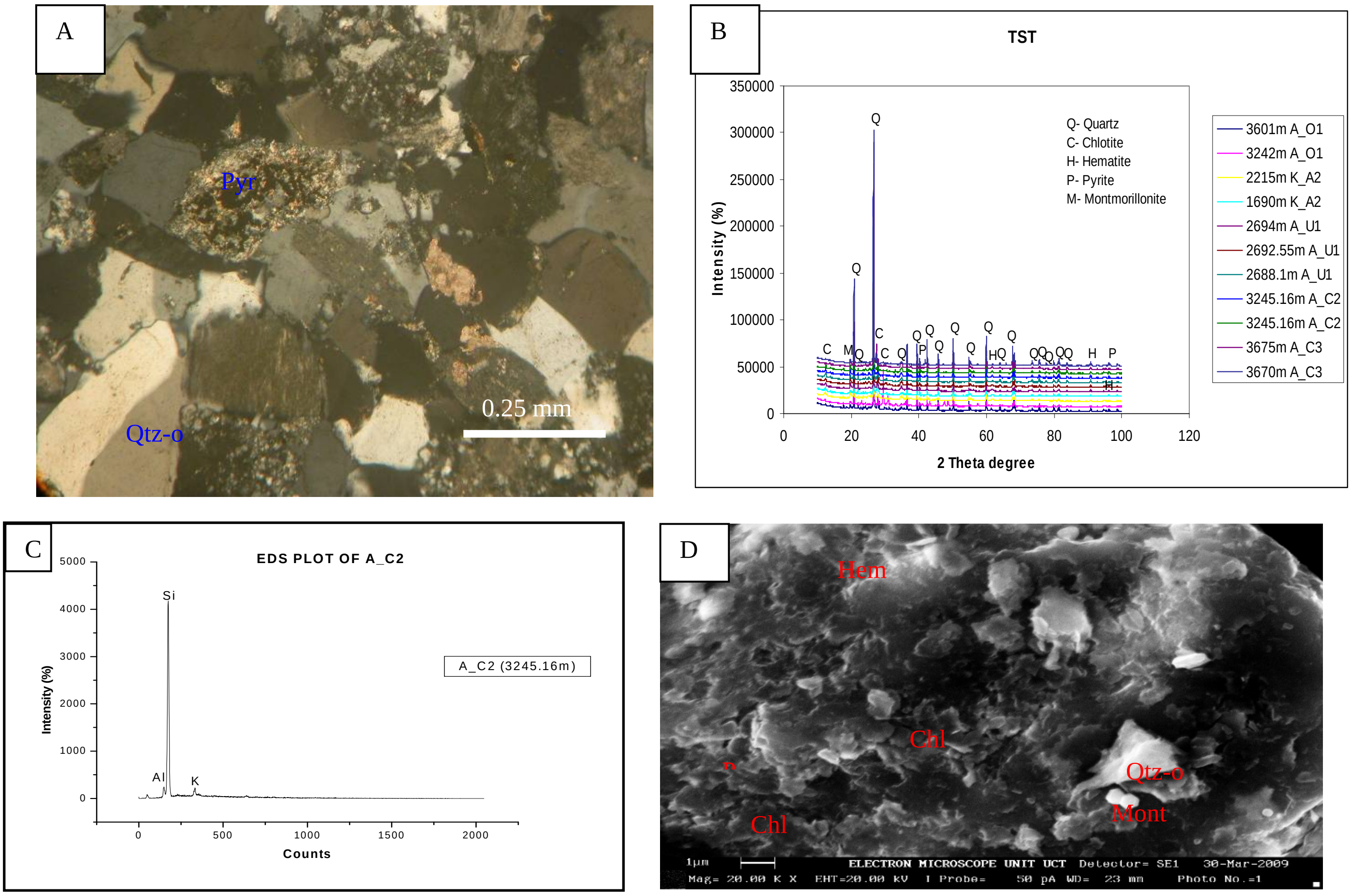

Fig 3. Results of analyses on sample collected within TST in well A_C2 at depth 3245.16m. (A) Thin section result. (B) The XRD result, (C) EDS result and (D) the SEM result.

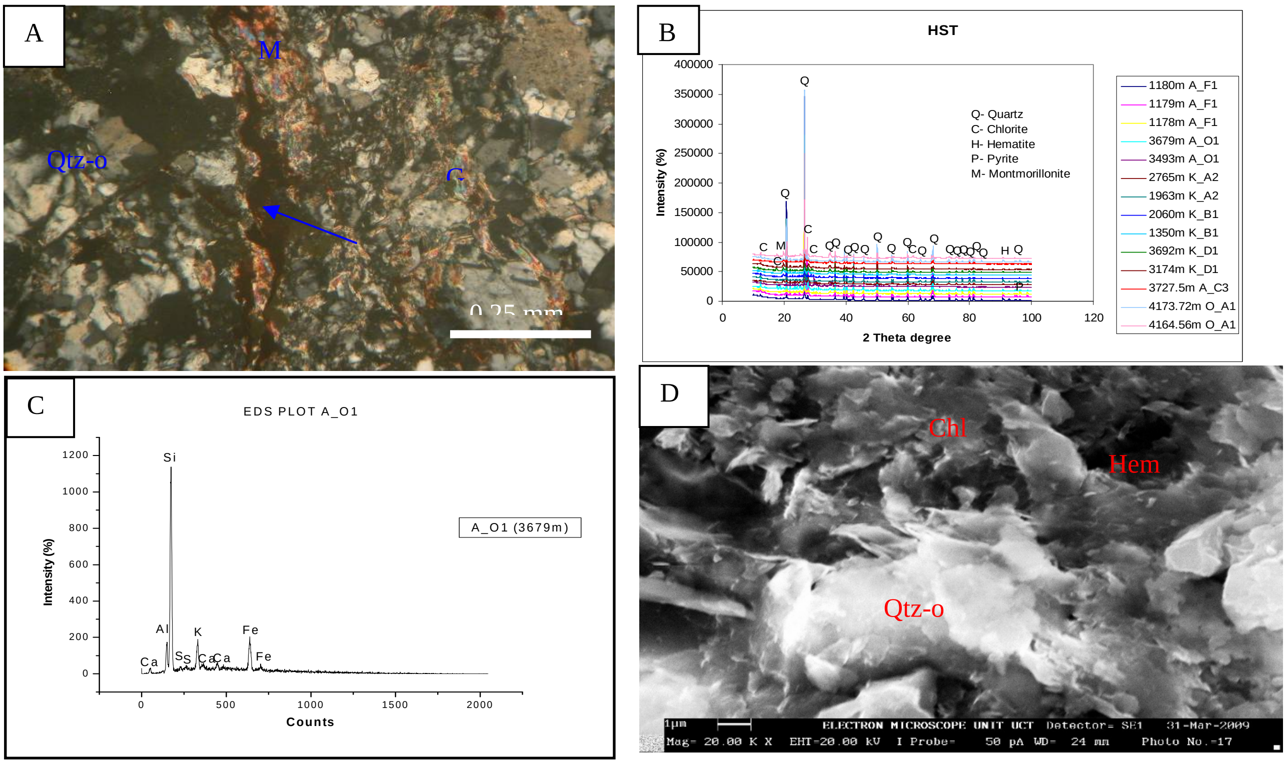

Fig 4. Results of analyses on sample collected within HST in well A_O1 at depth 3679m. (A) Thin section result. (B) The XRD result, (C) EDS results and (D) the SEM result.

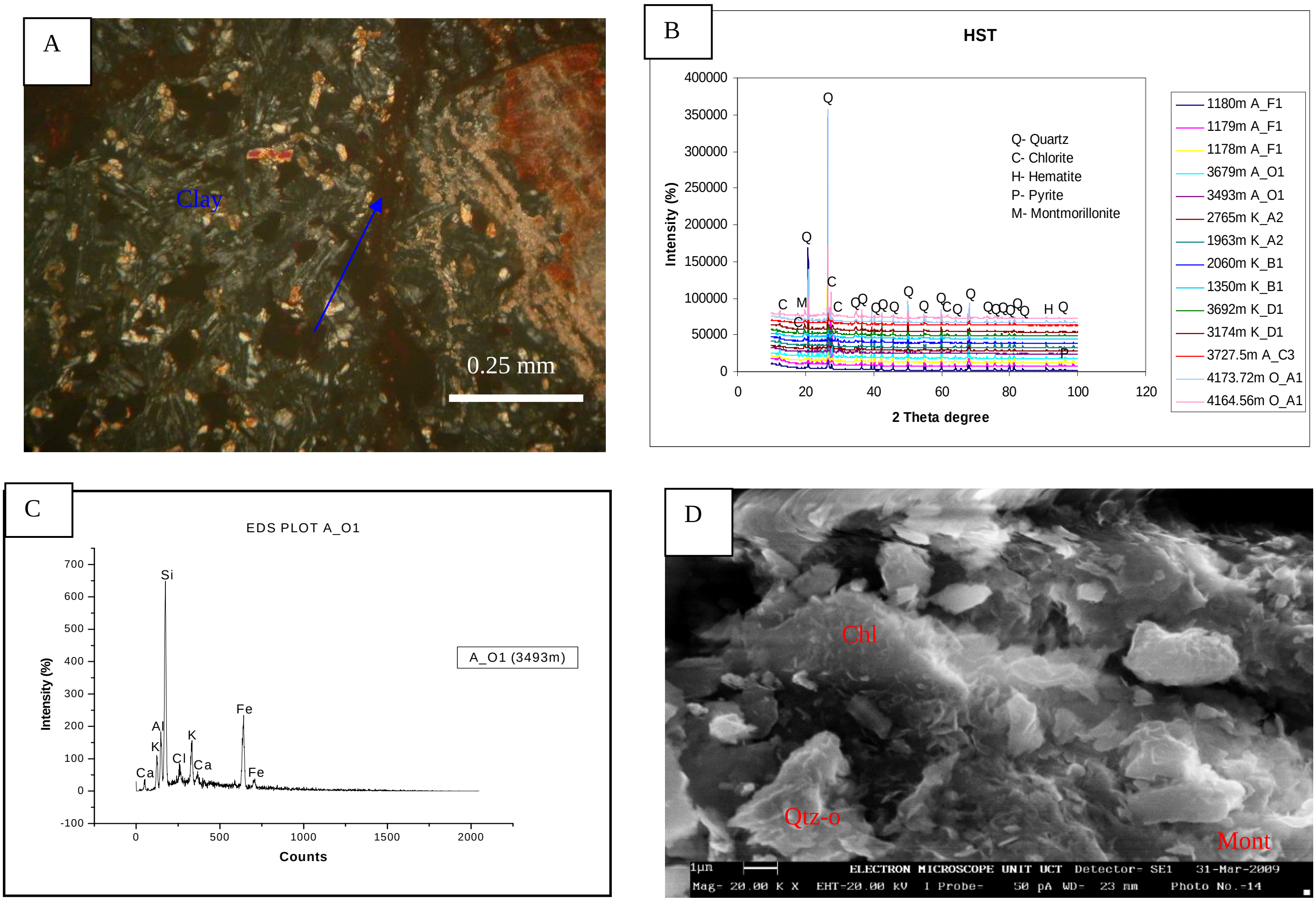

Fig 5. Results of analyses on sample collected within HST in well A_O1 at depth 3494m. (A) Thin section result. (B) The XRD result, (C) EDS result and (D) the SEM result.