Δελτίο της Ελληνικής Γεωλογικής Εταιρίας τομ. XXXX, 2007
Πρακτικά 11ου Διεθνούς Συνεδρίου, Αθήνα, Μάιος 2007

Bulletin of the Geological Society of Greece vol. XXXX, 2007
Proceedings of the 11th International Congress, Athens, May, 2007

APPLICATION OF BEDS THICKNESS DISTRIBUTIONS IN TURBIDITE DEPOSITS OF MAVRI MITI AREA, SW GREECE

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Abstract

A physical outcrop, of 100m length and 110 m total thickness studied in combination with sedimentological analysis in detail (stratigraphic sequence, grain size, sedimentological structures) led us to determine the sedimentological environments and the particular subenvironments of each part of the partial stratigraphic sequence which is a proximal depositional environment. The sandstone bed thickness data measured in Mavri Miti area, demonstrates a curved distribution shape in the log-log plots. Where processes such as erosion and bed amalgamation are more significant there was observed a possible deviation from the power-law statistical distributions. The shape of cumulative distribution demonstrates possible proximal fan setting. The above two different approaches shows an agreement in relation to the depositional processes.

Key words: *submarine fans, turbidites, bed thickness analysis.*

Περίληψη

Οι αποθέσεις υποθαλάσσιων ριπιδίων στην περιοχή του Αράξου μελετήθηκαν σε μία τομή μήκους 100m και συνολικού πάχους 110 m. Η λεπτομερής ιζηματολογική μελέτη των αποθέσεων μας οδήγησε στον προσδιορισμό του περιβάλλοντος ιζηματογένεσης, αλλά και των ιδιαιτέρων υποπεριβαλλόντων απόθεσης κάθε τμήματος της ακολουθίας των ιζημάτων. Ένα από τα πλέον αποδεκτά εργαλεία της στατιστικής ανάλυσης των τουρβιδιτικών ακολουθιών, το οποίο χρησιμοποιείται κατά κόρων, είναι η λογαριθμική κατανομή .Σ' αυτή συνήθως προβάλλεται ο δεκαδικός λογάριθμος του πάχους των στρωμάτων στον άξονα χ και ο δεκαδικός λογάριθμος του αριθμού των στρωμάτων που είναι παχύτερα από ένα συγκεκριμένο στρώμα στον άξονα ψ. Μετά τη δημιουργία της κατανομής μελετάται το σχήμα της (ευθεία, καμπύλη) και η μαθηματική εξίσωση που την εκφράζει (λογαριθμική, εκθετική), από όπου εξάγονται συμπεράσματα σχετικά με το περιβάλλον απόθεσης των τουρβιδιτών.

Λέξεις κλειδιά: *υποθαλάσσια ριπίδια, τουρβιδίτες, ανάλυση παχών στρωμάτων.*

1. Introduction- Geological setting

The study area is located in the NW part of Peloponnesus peninsula, is a part of Pindos foreland basin and geotectonically belongs to the Internal Ionian Zone. Pindos thrust activity, during Eocene, formed the Pindos foreland in the pre-existing Ionian and Gavrovo geotectonic zones (Underhill 1985, Clews 1989, Avramidis 2000, Vakalas 2003). The material with which the foreland was supplied, sourced from Eastern, from the forehead of Pindos thrust (Piper *et al.* 1978, Fleury 1980, Clews 1989, Wilpshaar 1995). Mavri Miti sandstone formation represents a turbidite system deposited during early Eocene, in an elongated basin where the major flow was perpendicular and the minor flow was axially, parallel to the Pindos thrust (Fig. 1).

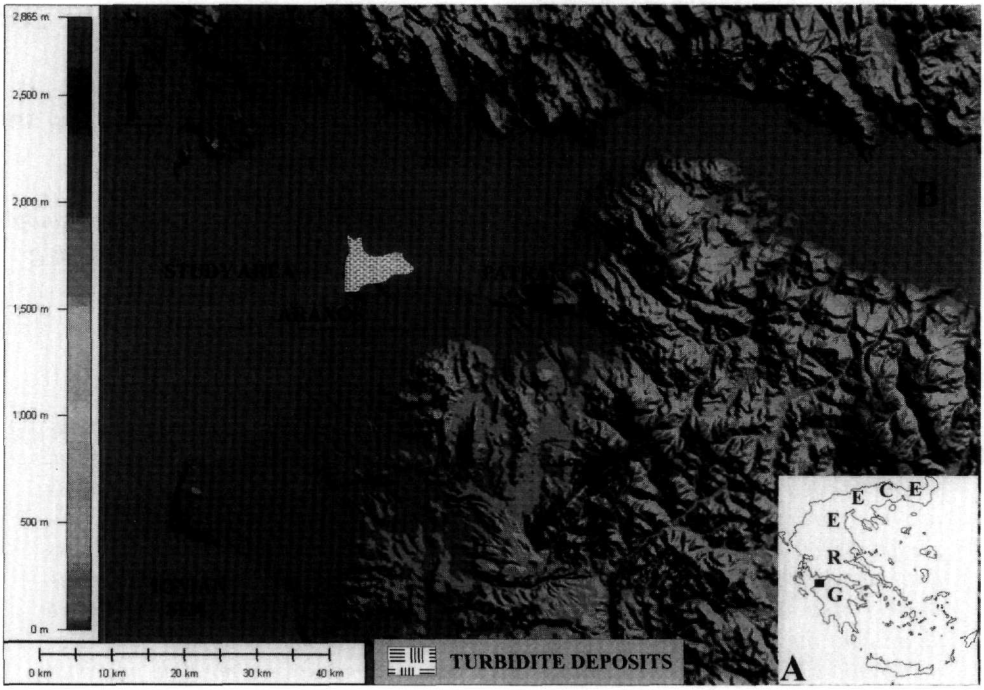

Figure 1 - Geological map of the North-Western part of Peloponnesus. The insert box represents the study area shown in figure

Generally basin analysis provides distinctions between depositional environments, whereas in the case of petroleum reservoirs, this distinction may highlight insight into fluid expulsion, pathways and reservoir geometry. Moreover, turbidite thickness distributions may help to reveal the extent of sand and shale interfingering, which can affect porosity and permeability patterns. The study of bed thickness distributions of various facies can help to identify important reservoir facies within the inner part of fan lobes, where massive and pebbly sandstones are relatively coarse and thick, with fewer and thinner shales between beds (Carlson and Grotzinger 2001).

In turbidites, the frequent interbedding of sand and shale strongly influences the overall heterogeneity of the resulting succession and the distribution of turbidite bed thicknesses is important in modelling and developing hydrocarbon reservoirs that were deposited in deep water (e.g., Flint and Bryant 1993, Tye 2004, Pyrcz *et al.* 2005). Turbidite bed-thickness distributions are often interpreted in terms of power-laws, even when there are significant departures from a single straight line on a log-log exceedence probability plot. It has recently been suggested that turbidite bed thicknesses can be well described by a log-normal mixture model (Talling 2001).

For the present study we used Carlson & Grotzinger methodology who deals mostly with cumulative log-log plots. This was the aim of this paper, a detailed analysis of turbidite bed thickness trend (based on bed thickness distributions using log-log cumulative plots) from the Mavri Miti formation in order to extract information about the geological conditions and the sedimentological characteristics of the turbidite deposits that might generate a power-law distribution, and how departures from it might be used as a guide to prediction of the submarine fan environment.

2. Sedimentological data

2.1. Description

Mavri Miti section consists of alternated fine-grained beds of light brown claystones and sandstones. In its upper stratigraphic part, beds of coarse grained sandstones and grits up to two meters thick appears. In order to approach the best sedimentological analysis of the studied sediments, the whole 110 m thick section (Fig. 2) of Mavri Miti sediments was separated in four parts and from the lower to the upper we have:

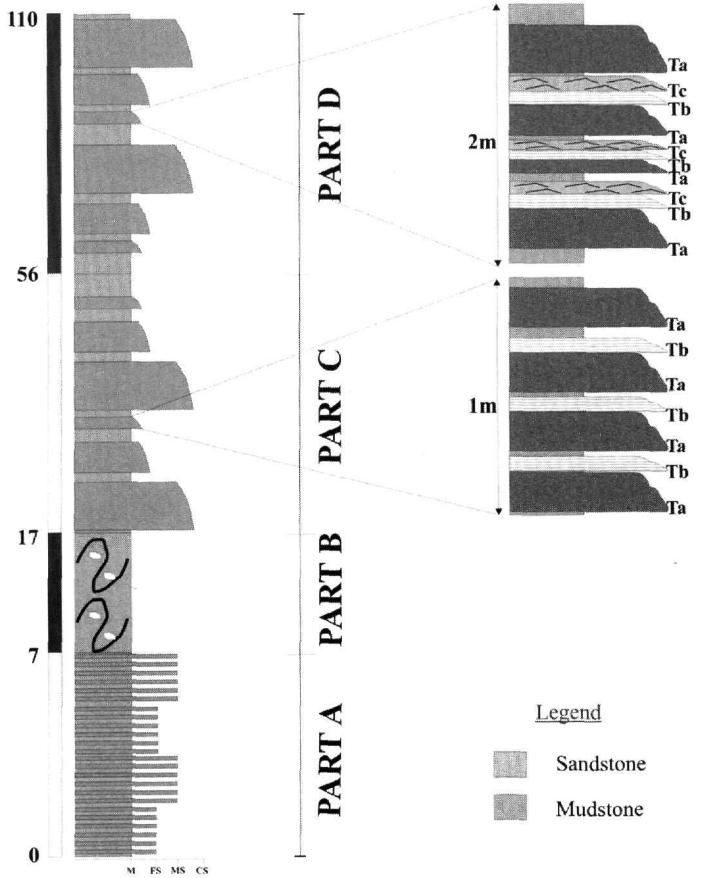

Figure 2 - Stratigraphic column of the studied sediments, not in scale, showing the four parts of the studied area

Part A: The total thickness of the lower part is up to 7m (Fig. 3A). It consists of thin-bedded fine to medium-grained sandstones, 1-7cm thick, with flat bases and very good lateral continuity interbedded with shales. Sandstone/shale ratio is 1/1. Ta Bouma subdivision characterizes sandstone beds, whereas Te Bouma subdivision characterizes claystones.

Part B: A slump horizon with thickness up to10m rests unconformably over the lower part (axis: 160^0, limb: $108^0/82^0$ for the slump) (Fig. 3B). Moreover, within the slump horizon a limestone lence was recognized interbedded with grey coloured mudstone matrix (Fig. 3C). The lence is up to 0.7 m thick and 5m length. This limestone seems to belong to Ionian zone and especially is similar to the Eocene limestones appeared westwards of the studied area.

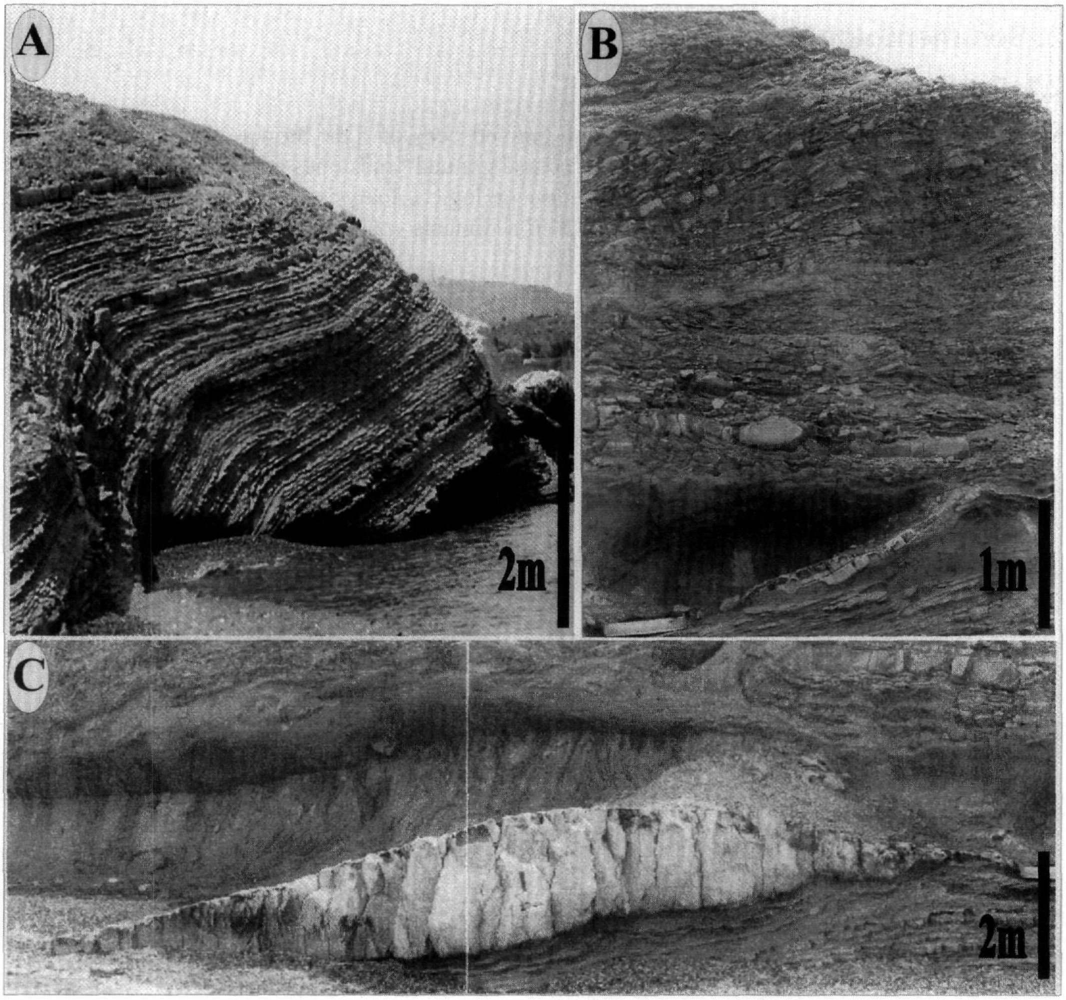

Figure 3 - A) Interchannel deposits in the lower part. B) Slump horizon. C) Limestone lence recognized in a slump horizon, interbedded with grey coloured mudstone matrix

Part C: Medium to thick-bedded sandstones, 10-96 cm thick, interbedded with shales, minimally amalgamated (Fig. 4A). The whole package is up to 40 m thick. Massive Ta units are the most common Bouma subdivisions in the section (70 % of the turbidite subdivisions), whereas Tb units are also common. Sole marks are prominent at the base of sandstone beds and include grooves and scours. The main palaeocurrent trend is WNW-ESE and the minor is ENE-WSW. Packages consisting of laterally continuous interbedded sandstones and shales with an upward-thinning trend. Thick laterally continuous sandy turbidite and slurry beds are also present throughout the section, often containing water-escape structures (dishes, pipes). Generally beds show an ENE dip direction with a dip of 9^0.

Part D: In the upper part of the section sandstones interbedded with shales, with a total thickness up to 55 m and showing an upward thickening trend (Fig. 4B). This stratigraphic part is dominated by Tabc and Ta Bouma sequences (60 % of beds), and which form at places packages up to 10 m thick, whereas Tbc Bouma sequence is common. Complete Bouma cycles and horizons of massive ungrained sand are also present at places in this unit. Toolmarks can easily been seen on the bottoms of thicker deposits, although scourmarks are rare. The main palaeocurrent trend in this part is

NW-SE and NNE-SSW as it results from the measurement of ripples ($308^0/21^0$, $24^0/25^0$). Beds show an E dip direction with a dip of 15^0.

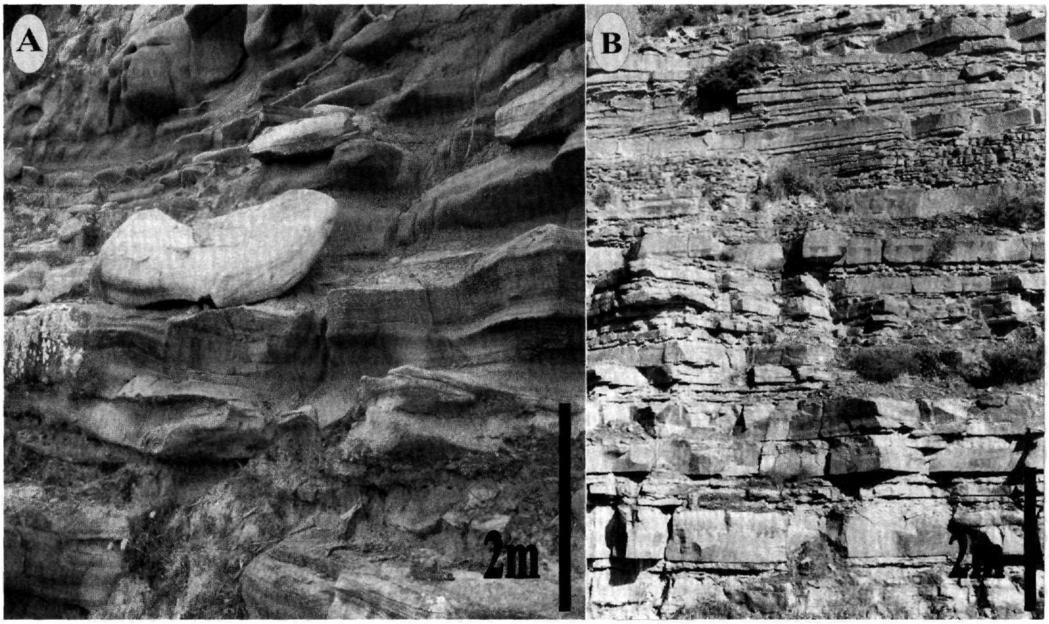

Figure 4 - A) Thick-bedded sandstones minimally amalgamated. B) Tabc Bouma sequences, form packages up to 10 m thick

2.2. Interpretation

The presence of Bouma sequence indicates submarine fans deposits. Ta and Tb Bouma subdivisions in the sandstone beds shows rapid deposition by high-density turbidity current (Bouma, 1962). The deposition of thin-bedded sandstones derived from low-density turbidity currents. Thin-bedded sandstones interbedded with clays derived from middle to low density turbidity currents. Especially, each part of the section is interpreted as:

Part A: The Tae turbidite beds are interpreted as inter-channel deposits from high-density currents involving mass deposition, followed by suspension fall-out with or without later chemical precipitation of chert (Eriksson 1980).

Part B: The slump horizon can be interpreted as a possible submarine rock falls deposit or landslides using as surface of slipping overpressure or liquefied clays. Hemipelagic and turbiditic shale is associated with the thin-bedded intervals. Although it is difficult to separate hemipelagic shale from low-density, dilute turbidite shale, we interpreted these deposits as low-density turbidite shale (Chester 1984).

Part C: This part has been described as close-to-source version of classic turbidites interpreted to have formed within broad channels (Lowe 1982). So, these deposits are interpreted as inner fan deposits. Given that beds extend without substantial changes in thickness for hundred of meters and are also noticeably lenticular, this suggests that the trend of the outcrop is perpendicular to the channel axis. Thick laterally continuous sandy turbidite and slurry beds, containing water-escape structures are interpreted as deposits derived from both debris flows and turbidity currents.

Part D: The Tabc turbidites are interpreted as middle-fan deposits passing west into outer fan deposits in Evinochori area (Pantopoulos *et al.* 2006). Complete Bouma cycles are considered to have accumulated on interchannel reaches of the middle-fan.

3. Statistical analysis

3.1. Methodology

The data sets consist of one measured vertical sequence of continuously exposed turbidites. Because of the inability of distinction between the turbiditic and hemipelagic mud the measurements were restricted to the arenaceous component. Any discernible bed was measured, although bed resolution typically diminished markedly below 1cm. For this reason, a minimum cut-off of 1 cm was established. Where the bed is disrupted and contains preserved bedforms (ripples, etc.) or has been eroded, the determination of the bed thickness becomes complicated and in such cases a number of measurements of the same bed were recorded and the average was used as the bed thickness. In the course of measurement, the thickness of individual sand beds is recorded, regardless of whether or not the beds are inferred to represent a single flow or multiple flows that have been amalgamated to form a single sand bed. This is an important distinction, in that the objectivity of the measurement is increased at the expense of an understanding of the actual distribution of the individual flows. In this manner, the statistical distributions of bed thickness may reflect successions of strata where amalgamation is minimal vs. those where amalgamation is common (Carlson 1998).

3.2. Application

In the studied up to 110 m thick whole section 514 beds were measured, 1 cm up to 150 cm thick (Fig. 5). The cumulative thickness distribution for this stratigraphic part yields a slightly curved shape. According to Carlson and Grotzinger (2001) this shape is consistent with an interpretation for deposition in a proximal environment (channelized, inner fan)

Moreover, we separated the studied section in order to applicate the statistical analysis only in the upper most part (Part D in the sedimentological chapter) with total thickness up to 55 m.In this second distribution data were collected from 132 beds, 1cm up to 140cm thick (Fig. 6). The shape of the cumulative thickness distribution is less curved than the first one, fits slightly better to a power-law and is considered to be diagnostic for turbidites deposited in more distal parts from the source environment(less channelized, middle fan).

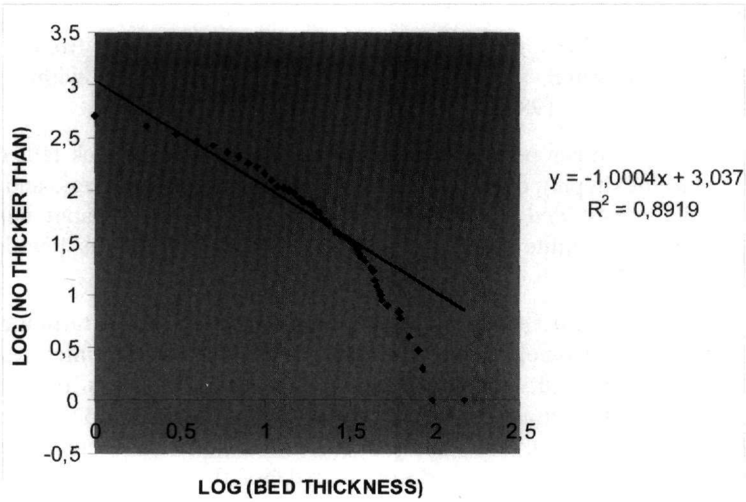

Figure 5 - A cumulative thickness distribution for 514 beds yields a slightly curved shape

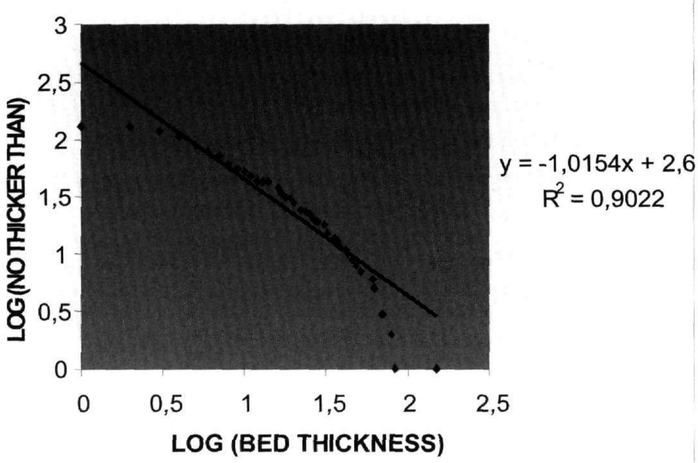

Figure 6 - A cumulative thickness distribution for the one-third of the section, 132 beds

4. Discussion and conclusions

Studied outcrop with a total thickness up to 110 m, composed by submarine fans, subdivided into four parts. In the lower part (Part A) the thin-bedded interval, interpreted as interchannel deposits, is considered to be representative of a different facies from the channel packages of the upper part, part D. The upward thickening trend in the upper part of the section is also considered to be representative of a different facies from the channel deposits, part A.

For statistical analysis we used two different approaches. One with the whole section and a second one only taking into account the upper part of the unit, Part D.

The sandstone bed thickness data measured in Mavri Miti area, demonstrates a curved distribution shape in the log-log plots. Where processes such as erosion and bed amalgamation are more significant there was observed a possible deviation from the power-law statistical distributions. The shape of cumulative distribution demonstrates possible proximal fan setting. The above two different approaches shows an agreement in relation to the depositional processes. Correlation between the statistical results of the whole section and the upper part shows that the upper part has a better fit to a power-law distribution whereas the whole part is more curved with a smooth departure from the power-law distribution, consisted with beds which are more affected by erosion and amalgamation.

From the above we could conclude that this method is in agreement with the sedimentological results and has successfully highlighted usefulness of using cumulative bed thickness distributions in submarine fan deposits.

5. Acknowledgements

This paper is coofounted by E.C., European Social fund and GSRT Greece. EPAN PENED '03ED497.We would like to thank anonymous reviewer for his helpful comments and suggestions.

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