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PhD (Doctoral) Dissertation Assessment
(Recenzja pracy doktorskiej)

Author: **Nguyen Van Kieu**
Title: ***Depositional architecture of the Quaternary succession in the southern Song Hong-Yinggehai Basin, offshore Vietnam: a sesimostratigraphic and sequence stratigraphic approach***

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1. Introduction

Sedimentary strata found along continental margins are a rich source of valuable mineral resources, with hydrocarbons being just one example. Beyond their economic significance, these geological formations also offer a unique window into the long and complex history of Earth's tectonic, environmental, and climatic evolution. Moreover, the structure and ongoing processes within these strata are increasingly becoming a cause for concern from a geohazard perspective. Consequently, it comes as no surprise that interdisciplinary studies focusing on continental margin sedimentary strata are gaining significant attention.

The final composition and arrangement of sedimentary strata result from a complex interplay of numerous factors. This includes the availability of accommodation space, which is influenced by processes such as subsidence and fluctuations in sea level. The supply of sediment to these areas is governed by various factors, such as topography, climate, bedrock types, sediment transport mechanisms, and depositional processes and patterns. Additionally, the early diagenetic processes that occur after sediment burial also play a pivotal role in shaping these formations. To study these sedimentary sequences comprehensively, a combination of diverse approaches is required, spanning various temporal and spatial scales. Researchers must understand modern, short-term sedimentary processes while also employing techniques like seismic studies to unravel the architecture of sedimentary strata, which can extend several kilometers in thickness and cover hundreds of kilometers in lateral extent, all formed over tens of millions of years.

Despite decades of research dedicated to continental margin sedimentary systems, numerous questions remain unanswered. Key areas of inquiry include the underlying driving mechanisms, the precise nature and quantification of sedimentary processes, and the intricate interactions between tectonic and climatic influences. Fortunately, ongoing technological advancements have brought about a wealth of new opportunities to address these questions. In-situ studies, the collection of lengthy sediment cores, improved dating techniques, and the integration of multiproxy approaches to sedimentary archives are expanding our understanding of these systems. Furthermore, advancements

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in seismic data quality and quantity, including the application of 3D techniques, are providing fresh insights into the formation, history, and structure of specific depositional basins.

This brings us to the PhD dissertation submitted by Nguyen Van Kieu for evaluation, which aligns with the current research trends in this field. Kieu's work is a rigorous investigation that delves into the analysis of approximately 2 kilometers of Quaternary sedimentary strata located in the Song Hong-Yinggehai Basin, offshore northern Vietnam. This research area holds particular international significance due to its location within the sphere of influence of the monsoon circulation, which is linked to major global climatic systems. Moreover, the region is situated within one of the most active tectonic zones, associated with the Red River Fault Zone.

The thesis represents a result of fruitful collaboration with the Vietnam Petroleum Institute (VPI), which has generously provided access to an extensive array of datasets, including 2D seismic reflection profiles and sediment cores. This valuable partnership has enabled Nguyen Van Kieu to undertake a comprehensive exploration of the sedimentary strata in this region, shedding light on both the geological history and contemporary dynamics of this intriguing and scientifically significant area.

2. General description of the thesis

The thesis is in the form of an unpublished monograph written in English (156 pages in total). It is composed of the table of contents, acknowledgments, abstracts (in Polish and English), lists of tables and figures, the eight major chapters, and references. The chapters contain three introductory parts (28 pages), namely introduction, physiographic and geological setting, and database and methodology. They are followed by chapters presenting the results (88 pages): sedimentological and biostratigraphic analyses, seismic stratigraphy and clinoforms/clinothems, and sequence stratigraphy. The last two chapters (only 7 pages) are discussion and conclusions. The thesis is illustrated with 67 figures, including several large folded sheets presenting seismic profiles and geological cross-sections.

The short (2.5 pages) introduction chapter presents the rationale of the research, objectives, and the structure of the thesis. The Authors point to the importance of a stratigraphic approach to study sediment basins and new opportunities related to new techniques and tools for seismostratigraphic works. The southern part of the great Song Hong-Yinggehai Basin with thick deposits, delivered by one the largest Asian rivers, e.g., the Red River, and containing the Quaternary shelf prism was so far understudied and the motivation of the Author was to fill this gap. The main aim is '*to gain detailed insight into the Quaternary stratigraphic evolution in the southern Song Hong-Yinggehai Basin, offshore Vietnam, where the shelf passes basinwards into a clinoformed shelf margin*'. This general and regional goal is subdivided into four specific objectives / research tasks:

- to identify lithofacies and depositional environments from sediment cores integrated with wireline logs,

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- to break down the Quaternary succession into unconformity-based seismic units and depositional sequences, as well as their constituent systems tracts derived from seismic correlation,
- to place the resulting stratigraphic subdivision within a chronostratigraphic framework interpreted from biostratigraphic data,
- and to acquire detailed insight into the stratigraphic architecture of the Quaternary succession in the southern Song Hong-Yinggehai Basin, in the Gulf of Tonkin, offshore Vietnam.

Chapter 2 (12 pages) presents the geography, topography, and geology (in particular stratigraphy and recent tectonism) of the studied region. The Author documents good knowledge of previously published results related to various aspects of the studied region. The chapter is generally well illustrated, although Figures 2.3 and 2.4 partly are not readable. It starts with a general description of Gulf of Tonkin (2.1.1) and of the large pull-apart Song Hong-Yinggehai Basin (2.1.2), followed by the geology of the latter. However, chapter 2.1.2 actually presents the geological setting so could be merged with 2.2.1. Chapter 2.2.2 (stratigraphy), provides actually a list of various previous works with short information about what was done. However, little is stated about the outcomes of these studies. The following subchapter 2.2.3 is dedicated mainly to examples of still ongoing diapir-related tectonic movements. The last, single-page, subchapter 2.3 "Study area", partly repeats the information contained in the previous parts. So, in general, chapter 2 seems to be a little bit chaotic, although it contains most of the information needed to understand the local setting. One could expect more information about the geology of the drainage area, tectonic evolution, oceanography and climate.

Chapter 3 (14 pages): 'Database and Methodology' presents the impressive study material analyzed in the study. The material was generally provided by VPI. It includes nine long cores (up to 2 km long) and a huge number of 2D seismic survey data. The wells (cores) were studied for biostratigraphic purposes (palynology, foraminifera, and nannofossils), and petrographic and sedimentological descriptions. Moreover, the well drilling was supplemented with wireline logs (including gamma measurements, etc.). The description of the analysis is relatively short, and many technical issues are missing, thus it is not fully clear if the Author was at least partly engaged in the analyses or used the provided results for his own correlation with seismic data. The major part of the chapter is dedicated to seismic stratigraphy. The chapter includes a long description of seismic stratigraphy and sequence stratigraphy basic concepts and terminology, in particular in regard to clinoforms, providing evidence of a good understanding of the topic by the Author. However, the actual description of the applied methods and available material is relatively short. The seismic data analysis and interpretation were done using Opendtect, PaleoScan™ and Petrel software. The available data were analyzed using the "reflection termination mapping" approach with a particular focus on clinoforms and their geometry.

Chapter 4 is dedicated to sedimentological and biostratigraphic data gained from well cores samples. The selected intervals of the wells studied in detail are presented and provides insight into the variability of sediments and environments in the studied system. The sedimentological descriptions and interpretations are condensed (2 pages + figures). All together, six lithofacies are

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identified: graded bedded conglomerate and pebbly sandstone, sandstone, interlaminated siltstone/sandstone and mudstone, massive mudstone, laminated mudstone and bioturbated mudstone. However, from the short description one may wonder if, for instance lithofacies 4 (massive mudstone) and 6 (bioturbated mudstone) are indeed so different. The facies are roughly assigned to possible depositional environment (from the outer shelf to intertidal and nearshore zone). This interpretation, although possible, is not supported by deeper discussion and in my opinion should be treated with caution. The foraminifera analysis, palynology and nannofossils are used mainly for stratigraphic purposes, defining various parts of the Pleistocene – these results are nicely summarized in Fig. 4.10. The foraminifera are also used to define subenvironments. However, most of the investigated taxa occur in various habitats, so this part I would also consider to be preliminary as the detail foraminifera data (counts, abundances, assemblages) are not presented.

The following chapter 5 is the longest part (32 pages) of the thesis and is dedicated seismic stratigraphy and clinothems. It is remarkably well illustrated by examples of various seismic profiles. The Author identified nine seismic facies, namely fluvial to shallow-marine transition, muddy shelf platform, deltaic foresets, prograding and upstepping shelf margin, channel/valley fills, massive-flow deposits, deep-marine condensed sections, shallow-gas migration zones and mud diapirs. It is stated that the identification was based on configuration, continuity, amplitude and frequency of seismic reflections and their termination pattern. Analyses of all the available seismic data led to identification of 25 key seismic horizons, which were correlated to each other and to investigated wells. The later allowed to date five of the horizons to 1.93, 1.6, 1.24, 1.06 and 0.78 My. Unfortunately, the figure presenting the correlation (Fig. 5.13) partly is not clear as the text font is far to small. The second major part of the chapter is dedicated to analysis of clinoforms. They are well presented in several figures and their geometrical parameters are combined in several pages-long tables. Five major types of clinoforms were identified, which are assigned to deltas prograding over the shelf or to aggrading continental shelf margin. The structures related to the later were also analysed in the context shelf-margin trajectories.

Chapter 6 is dedicated to seismic stratigraphy and combines results presented in earlier chapters. All together, 25 depositional sequences were identified and classify as lowstand system trackt, transgressive system tract, highstand system tract and falling-stage systems tract. The obtained results served as a basis for paleogeographic reconstruction, particularly focused on shelf margin progradation rate and maps (Fig. 6.21) presenting domination seismic facies distribution for all the identified sequences.

The next chapter is called discussion and is relatively short (5 pages) and focuses on three major topics. First, on the origin shelf margin clinoforms, role of the coastal topography and relation of clinoform type to gravity flow deposits. One may be a bit disappointed with such a short discussion after presentation of so extensive datasets, however, it must be underlined that actually many issues are already discussed in the earlier chapters. The following conclusions (2 pages) should be probably named summary as it is a compilation of key findings. There is a summary of answers to the key questions (objectives) asked in the introduction. Nevertheless, there are also included some

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suggestions related to hydrocarbon prospecting. The thesis is ended with extensive list of cited references (almost 200).

3. Assessment and comments

My general opinion about the presented doctoral dissertation is positive. The author presented a work based on high-quality analyzes of very rich and unique research material. The author showed a very good knowledge of the current literature related to seismic stratigraphy, as well as to the studied area. He proved that he can identify the problem, formulate research objectives, apply appropriate methodology and critically discuss the results.

The thesis is written in correct English, although some awkward sentences are occasionally found. The figures are mainly of high quality, the major problem is that sometimes the font of text is much to small or the scale is not straightforward (if there is a single scale for many panels, then it should be stated in the caption). The general structure of the thesis is correct, however, particular parts could be improved as already suggested in the description above.

Without diminishing the high evaluation of the doctoral dissertation, it is also necessary to pay attention to some shortcomings and to some emerging questions. Taking into account the wealth of the presented data it is a bit disappointing to see the discussion to be focused mainly on the interpretation of them in local to regional context. It is stated that the sedimentary succession is slightly different than other similar successions worldwide and it is ascribed to the local conditions and presence of the embayment. I would be happy to see it more elaborated, and the critical boundary conditions, which make the difference, to be quantified. Although, I am aware that it is not easy without conducting numerical modeling etc.

Another intriguing issue is related to the types of clinoforms. It is probably the topic studied in the most detail way. However, the identified two major types of clinoforms seem to miss a clinoform related to mid-shelf mudbelt, common along most of the east Asian continental shelves, including also the shelf off central Vietnam. I would be happy to discuss this issue during the public presentation and discussion of the thesis. Are the modern sediment distribution patterns unique in the time scale of Quaternary?

One of the open questions in related to sediment sources. The Author touched the problem, however, it seems that a straightforward answer is difficult. In the recent years a new depocenter next to Hainan Island was identified (the delta described for instance by Zhang et al.), could the Hainan be also significant sediment source for the studied basin?

The last question is of more general nature. The presented Quaternary succession is up to 2 km thick, to accommodate such a thick sediment cover a substantial subsidence is also required. I would be interested in the Author opinion about the driving mechanism of that process and potential evidence elsewhere for the uplift to balance the disequilibrium.

4. Conclusion

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This thesis represents a great deal of work. The results are well presented and their interpretation is generally correct and satisfactory. I really appreciate the candidate's expertise in the field of application of seismic data regional analyses., as well as the attempts to incorporate also sedimentological and micropaleontological data. In my opinion, the dissertation by Mr Nguyen Van Kieu complies both with Polish and international standards for PhD dissertations in the field of geosciences.

Wniosek końcowy

Stwierdzam więc, że przedstawiona do recenzji praca spełnia wszystkie wymagania stawiane rozprawom doktorskim. Stanowi ona istotny, nowy wkład do dotychczasowej wiedzy i dowodzi, że Pan Nguyen Van Kieu w pełni opanował umiejętność prowadzenia badań naukowych. Recenzowana praca spełnia zatem wymagania określone w "Ustawie o stopniach naukowych i tytule naukowym oraz o stopniach i tytule w zakresie sztuki" z dnia 14 marca 2003 r. (Dz. U. z 2017r. poz. 1789 i ze zm.). Tym samym wnioskuję o dopuszczenie Pana Nguyen Van Kieu do dalszych etapów przewodu doktorskiego.

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