# CHARACTERIZATION AND ORIGIN OF DROPSTONE IN PENINSULAR MALAYSIA

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# CHARACTERIZATION AND ORIGIN OF DROPSTONE IN PENINSULAR MALAYSIA

by

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**Thesis submitted in fulfillment of the requirements for the degree of Master of Applied Science**

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بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ ١

۞مِنۡهَا خَلَقۡنَٰكُمۡ وَفِيهَا نُعِيدُكُمۡ وَمِنۡهَا نُخۡرِجُكُمۡ تَارَةً أُخۡرَىٰ ٥٥

55. From the clay We created you and into it We shall send you back and from it will We raise you a second time.

وَلَقَدۡ خَلَقۡنَا ٱلۡإِنسَٰنَ مِن صَلۡصَٰلٖ مِّنۡ حَمَإٖ مَّسۡنُونٖ ٢٦

26. And certainly We created man of clay that gives forth sound, of black mud fashioned in shape.

وَٱللَّهُ أَنۢبَتَكُم مِّنَ ٱلۡأَرۡضِ نَبَاتٗا ١٧

17. And Allah has made you grow out of the earth as a growth:

أَلَمۡ تَرَ أَنَّ ٱللَّهَ أَنزَلَ مِنَ ٱلسَّمَآءِ مَآءٗ فَأَخۡرَجۡنَا بِهِۦ ثَمَرَٰتٖ مُّخۡتَلِفًا أَلۡوَٰنُهَاۚ وَمِنَ
ٱلۡجِبَالِ جُدَدُۢ بِيضٞ وَحُمۡرٞ مُّخۡتَلِفٌ أَلۡوَٰنُهَا وَغَرَابِيبُ سُودٞ ٢٧

27. Do you not see that Allah sends down water from the cloud, then We bring forth therewith fruits of various colors; and in the mountains are streaks, white and red, of various hues and (others) intensely black?

## ACKNOWLEDGEMENT

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## LIST OF SYMBOL

| | |
|---|---|
| Ar | Argon |
| $Fe^{2+}$ | Iron (II) ion |
| $Fe^{3+}$ | Iron (III) ion |
| µm | micrometer ($1 \times 10^{-6}$ m) |
| mm | millimeter ($1 \times 10^{-3}$ m) |
| cm | centimeter ($1 \times 10^{-2}$ m) |
| m | meter (1 x 1 m) |
| km | kilometer ($1 \times 10^{3}$ m) |
| $km^2$ | Square kilometer ( Area=length times by width) |
| K | Potassium |
| Pb | Lead |
| U | Uranium |

## LIST OF ABBREVIATION

| | |
|---|---|
| BOD | Biological Oxygen Demand |
| D | Diameter (function of diameter measured in centimeter) |
| Fm. | Formation |
| GDFs | Glaciogenic debris flow deposits |
| Kg. | Village (Kampung) |
| LPIA | Late Paleozoic Ice Age |
| lv. | lithic (clay cementation) |
| N | North (direction with respect to earth magnetic pole) |
| NW | North West (direction with respect to earth magnetic pole) |
| Ma | Million years ago |
| Mc | Muscovite mica |
| Ort | Orthoclase feldspar |
| PPL | Plane polarized light |
| qz | Quartz (Silicon dioxide) |
| S | South (direction with respect to earth magnetic pole) |
| *sp*. | Species |
| Unimap | Universiti Malaysia Perlis |
| USA | United State of America |
| USM | Universiti Sains Malaysia |
| XPL | Cross polarized light |

**PENGELASAN DAN ASAL USUL BATU JATUH DI SEMENANJUNG MALAYSIA**


## ABSTRAK

Sekitaran pemendapan dan mekanisme batu jatuh di Malaysia masih dalam perdebatan, sama ada ia berasal dari glacio-lautan atau bukan glacio-lautan. Di samping itu, sumber batu jatuh di dalam diamiktit ini belum lagi diketahui. Oleh itu, kajian ini direncanakan untuk mengintegrasikan kajian lapangan geologi dan petrografi terhadap beberapa batu jatuh di Semenanjung Malaysia serta mengkaji asal usulnya. Di samping itu, pencirian batu jatuh di dalam diamiktit ini dapat memberikan pemahaman berkaitan sifat dan komposisi batuan asas yang tidak tersingkap di Malaysia. Pemerhatian lapangan dalam kajian ini menunjukkan bahawa berlakunya kejadian batu jatuh di Pantai Barat Semenanjung Malaysia termasuklah kepulauan Langkawi, Kedah, Perlis dan Selangor dari seawal usia Karbon-Perm. Batu jatuh di dalam diamiktit ini mempunyai julat saiz dari 2 sm hingga 20 sm yang bertaburan di dalam unit litologi yang berlainan seperti syal hitam, batu lumpur hitam, batu pasir dan syal kelabu. Kajian mineralogi dan petrografi menunjukkan bahawa batu jatuh ini terdiri daripada granit, kuarzit dan batu pasir. Salah satu batuan pengepong, yaitu syal hitam Formasi Singa mengandungi komposisi utama, iaitu ilite dan kaolinit. Kajian semasa menunjukkan bahawa batu jatuh di Semenanjung Malaysia berasal dari glacio-lautan. Batuan purba daripada batuan asas granit Pra-Kambria serta batuan kuarzit daripada Kambria Machinchang dan Kambria Jerai telah diseret oleh glasier dan dijatuhkan di kedua-dua batu pasir marin yang agak cetek dan syal yang lebih dalam. Kepelbagaian warna di dalam batuan pengepong mencadangkan keadaan pengoksidaan dan pengurangan semasa pemendapan batu jatuh. Hal ini berkait rapat dengan pembentukan batu pengepongnya. Walaupun

banyak diketahui tentang peristiwa global Zaman Ais Akhir Paleozoik, namun data dan penyelidikan yang terbatas mengenai Sibumasu sebagai sebahagian daripada dunia Zaman Ais Akhir Paleozoik masih kurang difahami. Oleh itu, kajian ini mencadangkan penambahbaikan hubungan serantau ke peringkat global jujukan litofasis yang memberikan tumpuan kepada Malaysia. Struktur deformasi (struktur drap) di bawah batu jatuh dan mekanisme pemendapan batuan pengepong bagi batu jatuh telah memberi pencerahan tentang sifat batu jatuh di Semenanjung Malaysia, iaitu diolah dari sumber glasial dan dimendapkan oleh mekanisme glacio-lautan.

**CHARACTERIZATION AND ORIGIN OF DROPSTONE IN PENINSULAR MALAYSIA**

## ABSTRACT

Depositional environment and mechanism of dropstones in Malaysia are still debatable whether they are of glaciomarine or non-glaciomarine in origin. In addition, the source of diamictites in these dropstones is not yet known. Therefore, this study was designed to integrate geological field observations and petrographic investigations on some of the dropstones in Peninsular Malaysia to examine their origin. In addition, characterization of diamictites in these dropstones can shed the light on the nature and composition of unexposed basement rocks in Malaysia. Field observations in this study indicated the widespread occurred of dropstones in West coast of Peninsular Malaysia including Langkawi archipelagos, Perlis, Kedah and Selangor of Carboniferous-Permian in age. Dropstone in these diamictite occur as rounded grains ranging in size from 2 cm to 20 cm that are scattered different lithological unit of black shales, black mudstone, sandstones and white shales. Mineralogical and petrographic investigations indicated that these dropstone are composed of granite, quartzite and sandstone. One of the host rock, Singa black shales is mainly composed of Illite and kaolinite. The current study suggests that the dropstones in Peninsular Malaysia are of glaciomarine origin. Older materials from the Precambrian granitic basement rocks as well as the quartzite from the Cambrian Machinchang and Cambrian Jerai quartzite were dragged by glacier to be dropped in both the relatively shallow marine sandstones and deeper shales. Varieties of colors of the host rock suggests the prevailing of relatively reducing and oxidizing conditions during the deposition of these dropstones in relation with the formation of its host rock. Although much are known about the global event of Late Paleozoic Ice

Age, yet restricted data and research on Sibumasu as a part of LPIA realm still poorly understood. This study suggest an improvement in regional to global relationship of LPIA lithofacies succession that focus on Malaysia. Deformation structure (draped structure) underneath the dropstones and mechanism of deposition of the dropstones host rock has enlighten the nature of Peninsular Malaysia dropstone, which are glaciogenic in origin and deposited via glaciomarine mechanism.

# CHAPTER 1

# INTRODUCTION

## 1.0 Background

Dropstone is an older clast of foreign rock fragment with variety of lithofacies and sizes, which is introduced in an oblique or vertical direction into heterogeneously finer sediment host by various depositional mechanisms driven by gravitational force (Bennett at al. 1996). Different depositional environments would result in different impact-deformation structure, distribution and frequency of dropstone throughout the space of the sedimentary host rock. The most recorded dropstone depositional mechanism is via glacier. Glaciation is not limited to continental part only, it can also cover the ocean surfaces such as dynamic earth magnetic poles, as an effect of celestial interaction which results in different temperature on earth's surface. In addition, earth's climatological influences such as tectonism, volcanism and meteorite impact has contributed to climate change throughout the geological time. Eyles (2008) suggested that several glacio epoch or ice age has occurred in alternating patterns starting with Neoproterozoic, Ordovician, Carboniferous, Permian, Cenozoic and lastly Quaternary, that chronological order.

As glaciation is common and seems to be the main dropstone transportation agent, specific geological terms have been introduced based on its depositional environment either on continental basin or oceanic basin. Flint (1960) used the term "diamictites" to describe a sedimentary rock originating from a wide range of lithified, non-sorted to poorly sorted, terrigenous sediments suspended in mud matrix sedimentary unit, instead of restricted only to glacier origin. Gaschnig et al. (2014)

used the term ‘tillites’ for dropstones that were deposited on land or continental basin rather than marine, and described diamictites as a universal unit which refers to dropstones which were deposited on land or marine environments. In general, there are four classes of dropstone rafting agents which are climatological such as glaciation, physical such as floating stone (pumice and coral), biological such as indigestible Gastrolith and projectile such as volcanic ejecta and meteorite. Thus, the origin of dropstone is not only restricted to glacier realm, but it can be anything that sticks to the earth’s gravitational force that emplace it into a new and completely heterogeneous and different environment as compared to the dropped clast itself.

The dropstone is a good indicator of paleoclimate implication during the past, such as a well-documented catastrophic event in sedimentary host rock. Glaciogenic dropstone bearing sediments were recorded as global reservoir for oil and gas such as Devonian diamictite of Libya and Morocco, and Carboniferous Permian West Australia Basin and South America in Brazil and Argentina. Dropstones also can be a part of geotourism attraction such as in Langkawi where it is well recognized as a Global Geopark under UNESCO.

## 1.1 Study areas

This study has been designed to study dropstone occurrences and origin over Peninsular Malaysia. Previous authors only focused on Singa Formation dropstone from Langkawi. Several locations of dropstone-bearing formations are reported in this study and can be simplified into three different sedimentary formations. Some of the localities were not reported yet by previous authors as dropstone-bearing formations. Based on their ages, dropstone-bearing formation from Malaysia belong to the

Carboniferous-Permian Gondwana glaciation episodes. Thus, the scope of this study can be narrowed down to Carboniferous-Permian sedimentary sequences in Peninsular Malaysia, of Langkawi, Perlis, Kedah and Selangor (Figure 1.1).

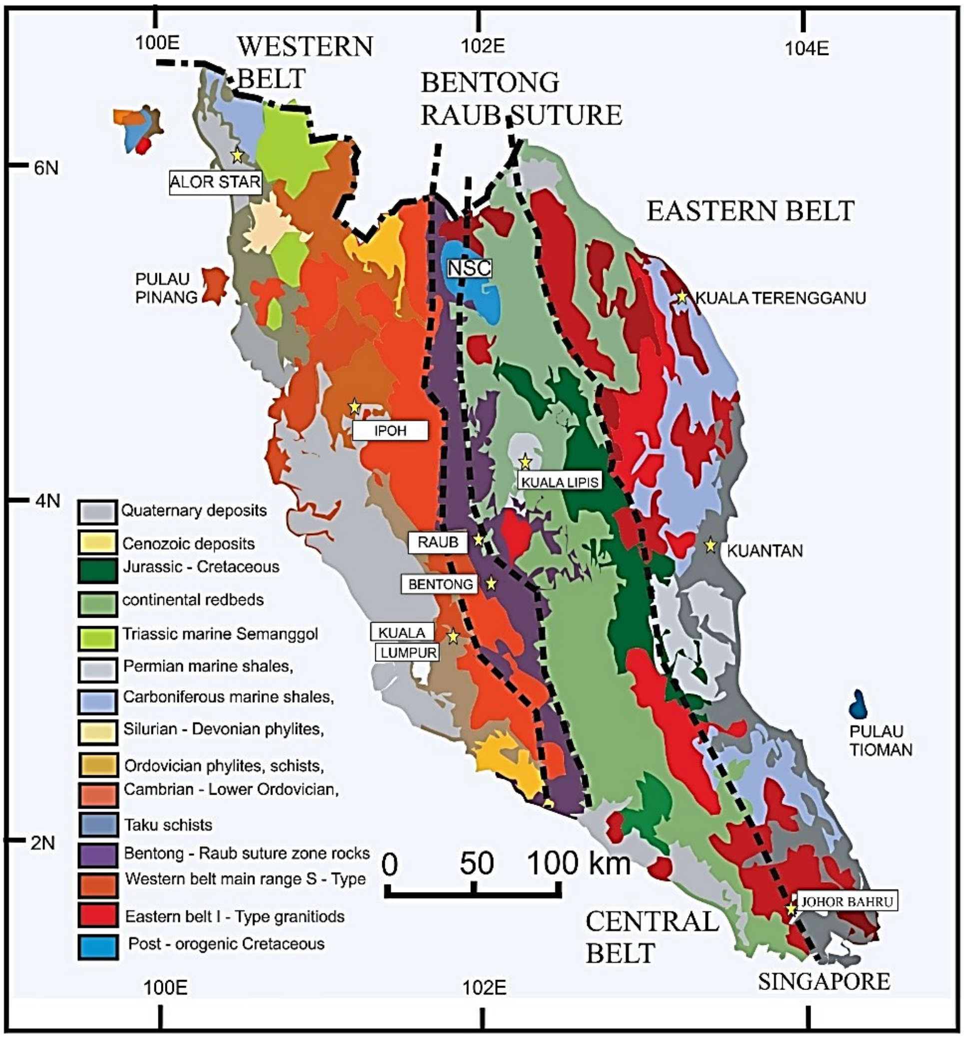


Figure 1.1: Geological map shows the distribution of Carboniferous-Permian sedimentary sequences from Peninsular Malaysia modified after, (Jabatan Mineral dan Geosains Malaysia, 2012).

Langkawi Island with 99 cluster of islands, located in the northern part of Peninsular Malaysia, in the state of Kedah (Figure 1.2). Generally, Langkawi Island has six different formations with five of them sedimentary in addition to the granitic intrusion (Lee, 2013). Machinchang Formation, which is the oldest known sedimentary outcrop in Malaysia is dominated by coarsening upward sequence quarzitic sandstone with subordinate conglomerate, siltstone and mudstone. The features of wavy bedding, cross beds, ripple marks with fossils of brachiopods and trilobite leads to interpretation of shallow marine and deltaic depositional environments. Machinchang Formation is overlain by the marine Ordovician Silurian Setul Group which is dominated by dark grey bedded limestone with at least two detrital band of black mudstone. It extends further on land to the state of Perlis. The next lithofacies reflects the change in sea level where regression took place and implication of the Late Paleozoic Ice Age, LPIA the shallow marine deposits influenced by the glaciation product of the Carboniferous-Permian Singa Formation that is composed of black to gray siltstone and mudstone. This alternating series of mudstone and siltstone were deposited with glacial derived material of dropstone with limestone lenses. It covers almost half part of Langkawi Island distributed along northeast-southwest direction. During this period of Carboniferous-Permian, Sibumasu started drifting northwards. This northward drifting and global warming resulted in the cycle of non-clastic sedimentary unit, with the deposition of Permian limestone of the Chuping Formation with light color, thin to thickly bedded limestone and dolomite as the basin goes deeper and more to equatorial region. The Triassic Gunung Raya Granite is predominated by coarse grained granite where some of it are porphyritic. Intrusion of these granites into older sedimentary rocks resulted in the formation of some metamorphic rocks such as marble, quartizite and horfels.

In this study, four locations of dropstone have been visited in Langkawi Island, which are Tanjung Mali, Pulau Tepur, Bukit Malut and Pulau Langgun. From that localities, 2 different lithology were identified and described as follow;

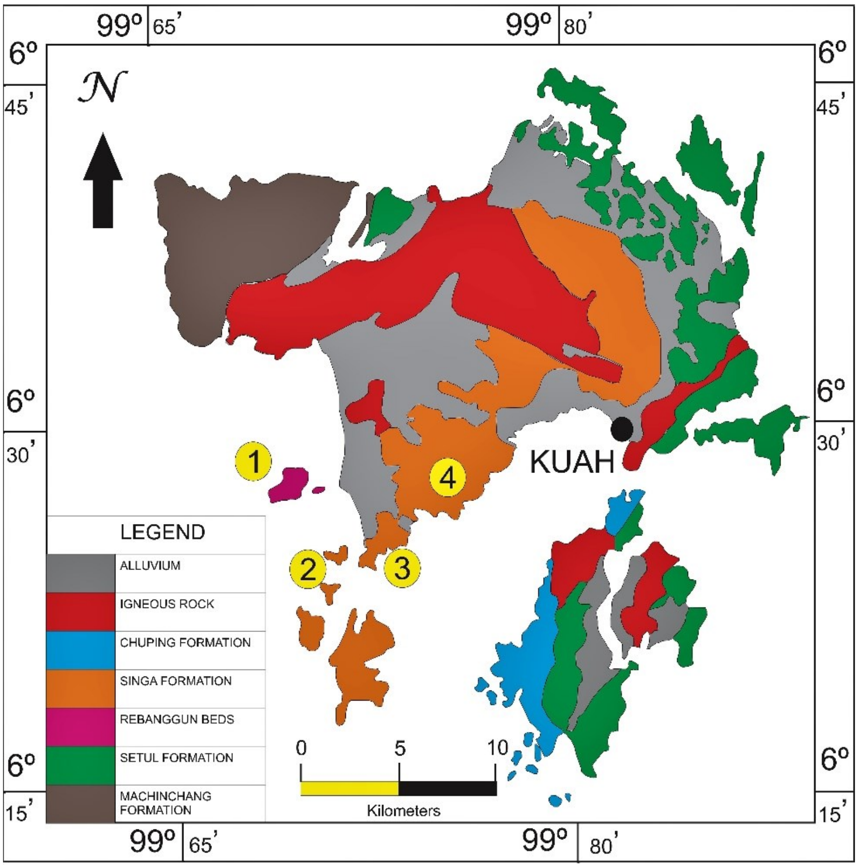


Figure 1.2: Geological map of Langkawi Island (Lee, 2013), shows the visited sites of dropstone; (1) Pulau Langgun, (2) Pulau Tepur, (3) Tanjung Mali and (4) Bukit Malut.

Perlis is located at the uppermost northern Peninsular Malaysia, border to Thailand with an area of 821 km². This small state represents the most variant of Paleozoic sedimentary sequence starting from Ordovician up to Permian (Figure 1.3). Ordovician Setul group consist of Middle to Late Ordovician Kaki Bukit limestone, Ordovician Silurian Tanjung Dendang Formation and upper part of Silurian Mempelam limestone. This pelagic Setul Group has received hemiplegic source of well bedded, black to grey colored quartzite, siltstone, shale and chert sediment that were preserved as Tanjung Dendang Formation. Overlying conformably on Mempelam limestone is Early Devonian Timah Tasoh Formation with gradual transition of thin bedded limestone to tentaculitid and graptolite-bearing black mudstone. This formation is overlain by the Late Devonian Sanai limestone. It is composed of bedded stylolitic mudstone and wackestone. Overlying the Sanai limestone is Carboniferous-Permian Kubang Pasu Formation which is subdivided into four units which are the (1) Telaga Jatoh Member; (2) Chepor Member; (3) Undifferentiated Kubang Pasu Formation; and (4) Uppermost Kubang Pasu Formation. Tournaisian Telaga Jatoh Member, is an important marker of Devonian Carboniferous boundary, it comprises of rhythmically alternating, cm-thick beds of black mudstone and dark colored chert. It is also local and just happens to be in small scale outcrop same to Sanai limestone. Then comes Visean Chepor Member which overlies Telaga Jatoh Member where it pinches out Chepor directly and overlies on Timah Tasoh Member is the Chepor Member, it consists of thick fossiliferous red mudstone interbedded with mainly tabular beds of quarzitic and feldspathic sandstone and occasional bedded diamictite. While previous studies suggest that the Chepor Member is deposited during Early Carboniferous, the latest discovery of the ammonoids *Goniatites* and *Praedaraelites* has further specified the age of the Chepor Member to the Visean. Next, lies conformably the Late Carboniferous Undifferentiated Kubang Pasu Member with thick red and grey mudstone, interbedded sandstone and diamictites that is similar to Chepor. So far, the classification of Undifferentiated Kubang Pasu Member, as “undifferentiated” is due to the lack of fossil evidences makes it age still remain unclear, even its lateral composition is extension by thickening of Chepor Member.

The Permian uppermost Kubang Pasu Formation succession is composed of several coarsening upward cycles of intercalation sandstone and mudstone with several features like bioturbidation, hummocky cross stratigraphy and ripple marks which represents wave and storm generated facies. The equivalent to the whole Kubang Pasu Formation and exist trending northward adjacent to it, is Carboniferous Permian Singa Formation that can be found to be at the border of Perlis-Thailand at a road cut outcrop to Wang Kelian. Even the same Singa Formation is extended from Langkawi to southern Thailand up to Phuket.

Then, the top of Perlis Paleozoic stratigraphy is Permian Triassic Chuping Formation that is also an extension from Langkawi. It conformably lies on Uppermost Kubang Pasu Formation and at another occasion in Perlis can be found in contact with Singa Formation Chuping limestone dominated by massive, light colored, rich in skeletal grains. The basal part is a wave influenced deposit in present of Hummocky cross stratigraphy structure which reflects the shallow marine deposition setting (Figure 1.3).

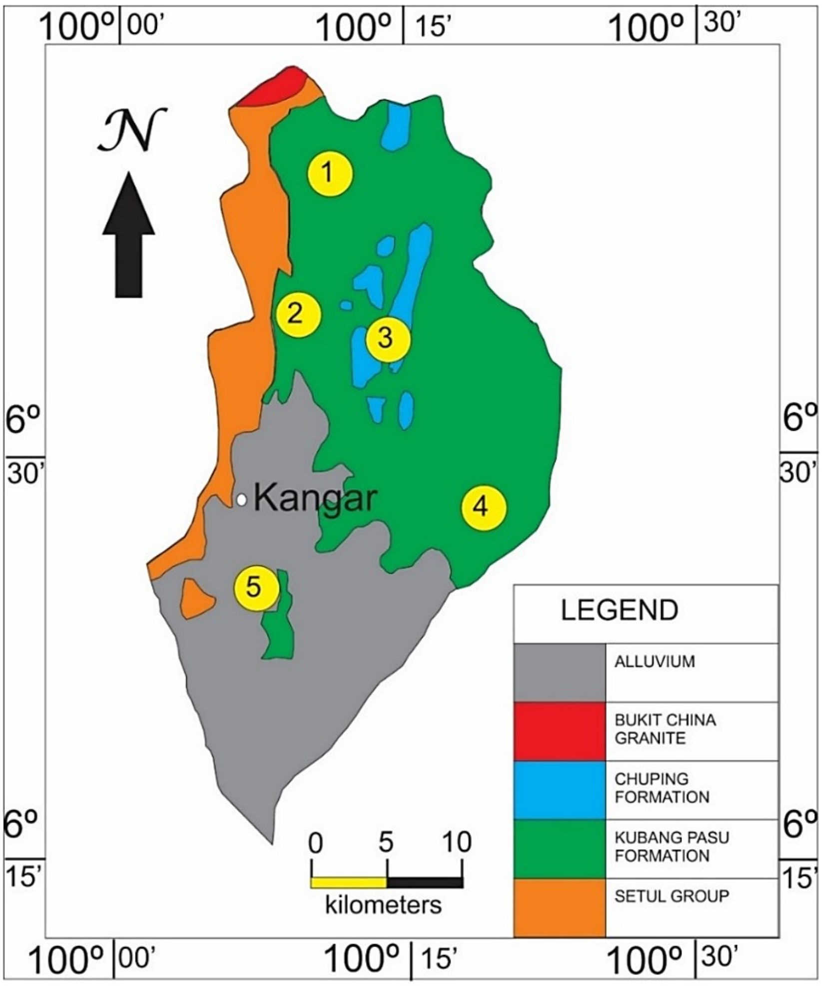


Figure 1.3: The geological map state of Perlis (Hakif et al., 2013), with numbered localities of dropstones occurrences; (1) Wang Kelian, (2) Guar Jentik, (3) Bukit Chondong, (4) Pauh, Unimap and (5) Hutan Aji.

The general geology of Kedah can be subdivided into three regions which are west Kedah-Perlis (including Langkawi), Perlis-Central North Kedah and East Kedah-Central North Perak. For the state of Kedah, this study covers the area of Perlis-Central North Kedah, where previous chapters has described this as west Kedah-Perlis region. There are no dropstone or diamictite bearing sediments observed inside Baling Group and Nenering beds of Perlis-Central North Kedah region. Overall, the distribution and geological boundary of the formation in Kedah is mapped such in (Figure 1.4).

Cambrian Jerai Formation is the oldest sedimentary rock in Kedah that only covers Gunung Jerai area which is located at the border of Kuala Muda and Yan district southwest of Kedah, facing the strait of Melaka with height of 1,217 meter. It is usually correlated to Cambrian Machinchang Formation in Langkawi due to the similarities in quartzite facies, yet the features on this quartzite are different as Jerai quartzite is a massive quartz arenite while Machinchang quartzite consist of metamorphose greywacke sandstone, laminated, cross stratified and contain trace fossils. Overlying the plutonic biotite granite with medium to coarse size grains intruded by pegmatite dyke is the oldest Jerai Fm. unit which is the argillaceous schist in grey color rich in biotite, muscovite, tourmaline and garnet. Silurian Devonian Mahang Formation covers southern Kedah just beside Jerai Formation.

Carboniferous Early Permian Kubang Pasu Formation in Kedah seems rather the same like Perlis where at some localities the red beds and grey mudstone coexists as one beds, with similar grains but different color clearly affected by weathering process. That makes Early Carboniferous Telaga Jatoh black shales conformably in contact with sandstone of Late Carboniferous undifferentiated Kubang Pasu Formation.

Middle Permian Grik Formation formerly known as Grik Tuff, distributed in the south eastern part of Kedah and locally can be found at Grik and Lawin area near the transcend area. Generally composed of metamorphose tuffs, rhyolitic to rhyodacitic volcanic dust, interbedded with limestone and calcareous shales.

Triassic Semanggol Formation form in turbidites that scatter in three region of northern Perak, southern Kedah and central northwest Kedah. The best outcrop was discovered in northern Perak, a village named Gunung Semanggol. Generally it can be sub divided into three units of; (1) Chert facies, bedded chert intercalated with mm thick of shales, (2) Rhythmic facies, intercalation of sandstone, mudstone and shales and (3) Conglomerate facies, dominated by conglomerate with minor intercalation of sandstone and shales.

The youngest unconsolidated Pleistocene Nenering beds which is also local to Felda Nenering near Pengkalan Hulu area, only covers 12km square area. With two different facies of; (1) Basal Gravel Beds Facies and (2) Gravelly Sand Layer Facies.

Kubang Pasu actually is a village name and also used to refer to a district in northern Kedah, yet there is no reported specific localities in this area. Thus, it leads this study to the Kubang Pasu Formation up till the Pendang district. It is an outstanding result as 3 active quarry sites were discovered with all of it having dropstone in the sandstone host rock.

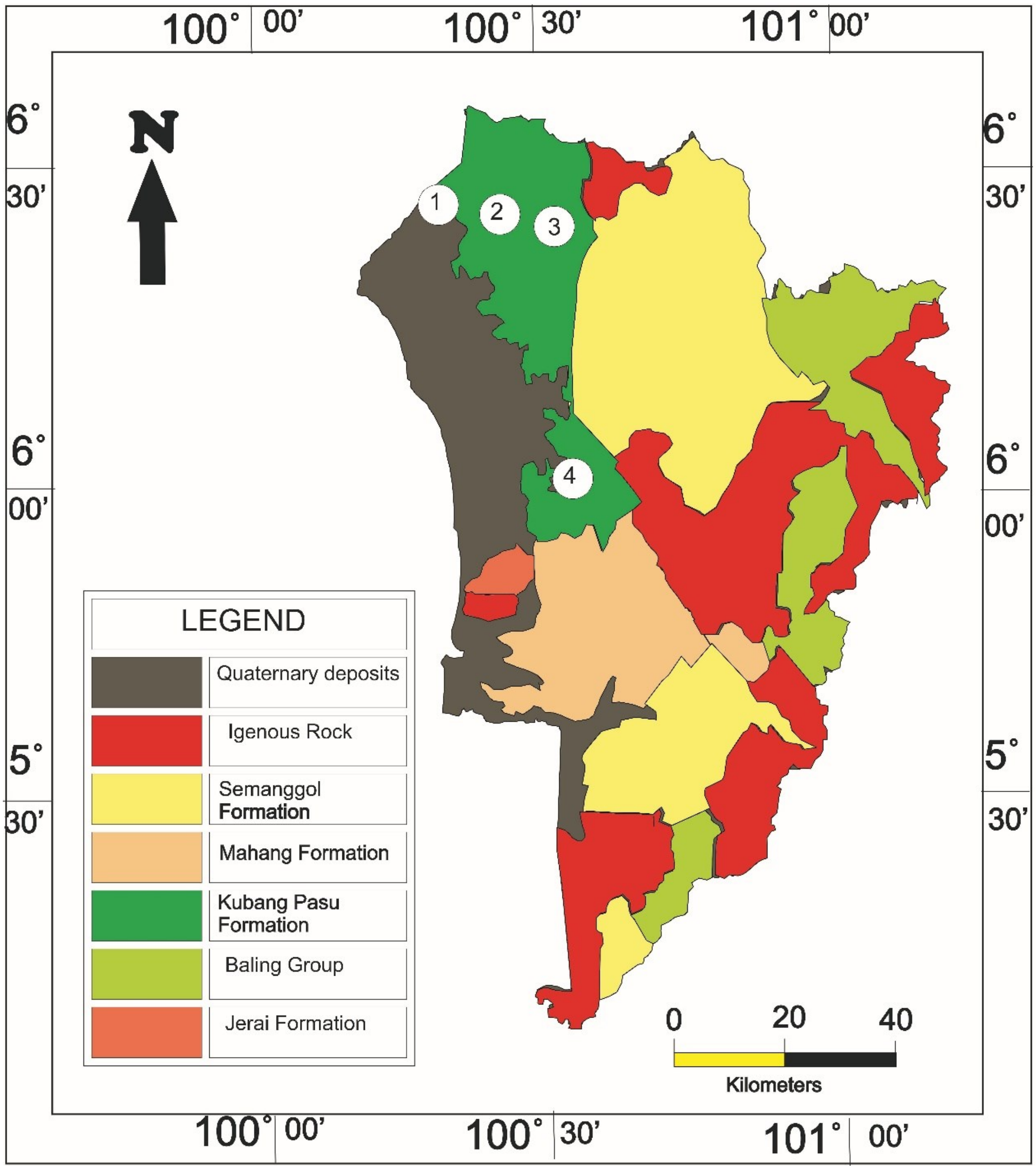


Figure 1.4: The geological map state of Kedah (Cocks et al., 2005), with number label refer to site localities of dropstone; (1) Kodiang, (2) Tunjang, (3) Bukit Malau of Jitra district and (4) Tanah Merah, Pendang.

Selangor is a state located in Central West Coast region of Peninsular Malaysia which is below the state of Kedah and Perak respectively. In the central part of Selangor state, lies the Federal of Kuala Lumpur, which is the capital city of Malaysia. Selangor with the size of 8104 km² land covers the area which is most economically important for Malaysia. The general geological boundary of various formation in Selangor is mapped in (Figure 1.5).

Ordovician Silurian Hawthornden Formation is the oldest sedimentary rock in Selangor that is distributed at Selangor central region extending eastward from Ulu Klang to Ulu Langat. It is classified into pelitic Hawthornden Schist and psammitic Dinding Schist. It is composed of quartz schist, mica schist, graphitic quartz schist and occasionally tourmaline quartz schist.

Middle to upper Silurian Kuala Lumpur limestone underlies low lying plain of north Kuala Lumpur extended and narrowing towards the southern town. This limestone hills forming ranges with pinnacles shape up to 300 meters thick where the lithology changes southward of Selangor to argillaceous and arenaceous Carboniferous Permian Kenny Hills Formation. Kuala Lumpur limestone has undergone regional metamorphism by Triassic granitic intrusion, where this dolomitic white clays grain limestone marmorised with small intercalation of phyllite and schist that is rarely found at the north part, but frequently observed towards the southern part.

Carboniferous Permian Kenny Hills Formation cover Kuala Lumpur area extended towards southern Selangor. This series of intercalation of quartzite, light color shale and occasionally phyllite is exposed at the basal part of Kenny Hills Formation. It has undergone low grade metamorphism that turns the series of sedimentary rocks into low grade metamorphic rocks. This formation is a comparative to Kubang Pasu Formation by its lithology and paleontological records, with even less trace fossils evidence found. Thus this makes the shales light in color compared to carboniferous shales deposited at the northern peninsula. The quartzite is examined to be angular to sub angular quartz grain cemented in silica matrix. Thinly layers of shales by mm thick are usually present within this yellowish brown quartzite.

Triassic Batu Arang sedimentary unit, the unconsolidated loss sediment comprised of two sub unit of Batu Arang bed and conglomerate bed. Miocene Batu Arang bed is the lowest part that consists of intercalated fine grains sediment sand, mud and shales with mm to 2 meter thick coal layer. Overlying it, is Eocene conglomerate bed with grey to reddish brown color. The sediment shows coarsening upward sequence, with fossilized leaf and pollen grains, thus interpreted to be deposited in lacustrine environment.

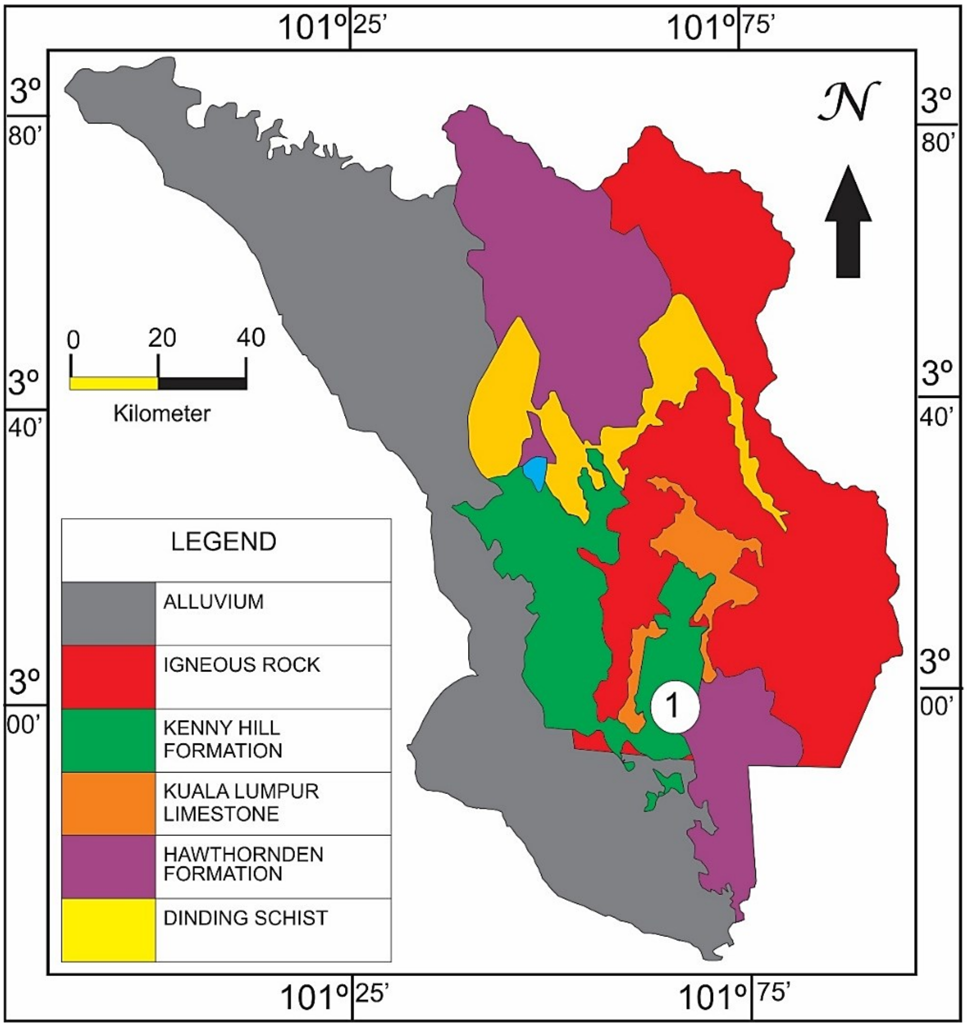


Figure 1.5: The geological map of Selangor (Harun and Jasin, 2003), label number 1, show the field location of Salak Tinggi, Sepang area.

## 1.2 Problem statements

A question mark left by previous researchers on how Malaysia's base looks like still remain unanswered until today. From the point of view of the continental drift theory, Malaysia is uniquely important to the history of the continental part existence. From the data recorded, Machinchang Formation in Langkawi was deposited at the age of Cambrian. It is the oldest known formation in Malaysia yet no discovery has recorded the basement of this sedimentary facies. Besides, Singa Formation that was deposited on Permian exhibit some unique lithological structure compared to other formation known in Malaysia – "The Dropstones". Unfortunately, previous studies such as (Altermann, 1986; Leman, 2003; Leman and Shi, 1998; Leman and Yop, 2002; Stauffer and Lee, 1989) only focused on this dropstone bearing sediment in Singa Formation, Langkawi Island. Whereas (Jones, 1981) has reported the extension of Singa Formation were found to be on the mainland of northern Perlis, but the dropstone inside it was poorly understood and reported. Besides, restricted studies by (Jones, 1981; Tjia and Isahak, 1990) described an occurrence of pebbly mudstone horizon inside Kubang Pasu Formation and Kenny Hills Formation. This dropstone or diamictites is uniquely distributed in Langkawi and Perlis including Thailand. The previous study had reported the existence in Langkawi region however it is not found in Perlis. Hence, from the recent research, it is believe that the dropstones were found in Hutan Aji and also in Universiti Malaysia Perlis main campus and extended to the northern Kedah region of Kodiang, Tunjang, Jitra and Pendang. Nevertheless the discovery has not been recorded in those locations mentioned. Perhaps, the discovery of the dropstone in Perlis, Kedah and Selangor can explain more about the environment of deposition during that period either it has the same properties and sedimentation or different settings to Singa Formation. This dropstone could lead to the findings of the basement in Langkawi or throughout Malaysia. According to (Alsharhan et al., 1993; Caputo et al, 2008; Lin et al., 2013) it was revealed that the evidence of Precambrian basements of Thailand, Oman and Parana Basin of Brazil were based on the glaciomarine deposition study of its characteristics. Moreover, only one attempt had been made to distinguish the dropstone in Malaysia and its facies properties by mineralogy study where it has described the possibilities of non–glacio marine sediments (Altermann, 1986). The results of non glacio-marine origin are still in debate and contradicts others research outcomes in Singa Formation and Kaeng Krachan Formation, Thailand. Although the Carboniferous–Permian glaciation records were well documented as evidence of glaciation-deglaciation sequences throughout the world with at least three major events, yet there is no attempt to classify these glaciation records and it is remain unclear in Malaysia. Furthermore, the unique depositional environment dropstone of Singa Formation exhibits greyish black shales compared to the other lithological units of oxidize mudstone yield yellowish reddish mudstone and phyllite such as in Salak Tinggi and Kubang Pasu. Are there any special conditions during the deposition of black shales dropstone in Singa Formation? Thus facies analysis is needed to identify what are the ingredients behind this diamictites. Thus it would be helpful to reveal the basement rock in Malaysia.

## 1.3 Research objectives

The objectives of this study are;

i. To identify and characterize the sedimentary facies of dropstone in Peninsular Malaysia and distinguish the dropstone lithology of three localities.

ii. To examine the possible source and the origin of the dropstones and its possible connection to the basement complex in Peninsular Malaysia.

iii. To compare and correlate the outstanding sedimentology and depositional environments/ geological setting of dropstones of Peninsular Malaysia in time and space.

iv. To resolve the controversy of the glaciomarine versus non glaciomarine origin of dropstones in Peninsular Malaysia.

## 1.4 Significance and novelty of the study

The study of dropstone in west Peninsular Malaysia, especially in Langkawi, Perlis, Kedah and Selangor shows some distinctive sedimentology and paleontological records from other parts of Malaysia. This study has resolved the controversy of glacial versus non-glacial origin of dropstone in Malaysia. It shed light on the nature of west Malaysia dropstone depositional mechanism, where it is not an ordinary glaciation product but it includes ocean as transportation mechanism. That is referred as glaciomarine deposits and the sedimentary unit can be recognized as diamictite horizon. Several diamictite horizon are recorded and suggest that West Malaysia dropstone were deposited by several glaciation episodes in Carboniferous to Permian era. Based on the field evidences and facies analysis, there are three types of rock that were identified as dropstone clast that are igneous, metamorphic and sedimentary rocks that ranges from Precambrian to Cambrian in age. The Precambrian granitic dropstone can possibly be a good indicator on how does west Malaysia basement looks like. Besides, this study has outlined the possible source or parent material of Cambrian dropstone clasts. Astonishing sedimentological records has been identified and classified based on their age and their occurrences are significant to each major glaciation episode of Gondwanaland during Late Paleozoic Ice Age. The outstanding result of this study will increase the regional to global relationship of dropstone occurrences and correlate the paleogeography and paleoclimate of Gondwana glaciation realm. This ideology of Gondwana glaciation episode of LPIA would change the way of how glaciation sedimentary rock were interpreted before in West Malaysia.

## 1.5 Layout of thesis

Generally, the contents of this dissertation are organized as follows;

Chapter 2 includes the literature review of previous study on the dropstone. Starting from the general concepts of dropstone and other related terms that are used to describe its properties. Then, its transportation agents and possibilities of occurrences based on localities. Next the dropstone occurrences and their geological background throughout the global event to regional and local in Malaysia.

Chapter 3 is devoted to research methodology. Firstly, it starts with the field observation of sites physical evaluations. Then, several initiatives were used to explain the dropstones facies within facies analysis discipline of petrography through Optical Microscope and mineralogy study.

In Chapter 4, the results of facies analysis is presented as pictures and tables with the analysis on their chemical, biological and physical properties to discover the sedimentological aspects of each dropstones facies.

In Chapter 5, the possibilities of the dropstone based on their uniqueness in a comprehensive expect is discussed. Each dropstone unit is classified and characterized.

Thus, this resolves the controversy of dropstones origin and that has not yet been discovered which represents the basement complex of Malaysia.

Finally, Chapter 6 concludes overall of the research on characterization and origin of dropstones in west peninsular of Malaysia, along with the recommendation for future study and sustainability of dropstone geology in Malaysia.

# CHAPTER 2

# LITERATURE REVIEW

## 2.0 Preface

This chapter describes the definition of dropstone from its mechanism of deposition, origin and distribution in local Malaysia, regional and global scale phenomena. Terminology of dropstone, diamictites and tillite were emphasized as according to the specific definition and lead for further analysis and classification including dropstones lithofacies. Then, it focuses on the global occurrences of dropstones to regional and local areas in Malaysia.

## 2.1 Dropstone

According to Bennett et al. (1994) a dropstone is a clast of an anomalous size, lithology that was introduced into the host sediment vertically or oblique to the bedding plane. It is an isolated fragments of foreign rocks found in finer grains of sedimentary rocks. While Flint (1960) used the term "Diamictites" to describe a sedimentary rock originated of wide range lithified, non-sorted to poorly sorted, terrigenous sediments suspended in mud matrix sedimentary unit, instead of restricted only to glacier origin. In addition, Tucker (2003) refer the diamictite as any poorly sorted terrigenous material and non-calcareous in general, that exhibit mixture of pebbles, sand and mud that lump together. Furthermore, a special characteristic has been made to emphasis the term glacial diamictites by Gaschnig et al. (2014), that describe glacial influenced diamictite as typically consist of angular and rounded clasts of variety sizes and shapes in a fine-grained matrix. While diamicton is a term to describe the un-cemented and unconsolidated diamictite (Tucker, 2003). Gaschnig et al. (2014) used the term ‘tillites’ for the dropstone that were deposited on land or continental basin rather than marine, and described diamictites as a universal unit referring to dropstone which were deposited on land or marine environments. Physically dropstone can be distinguished by naked eyes in a sedimentary rock as it is unique and isolated depending on their distribution in space. There are varieties in sizes, shape, sorting and angularity depends on their mode of transportation. The variation of size is from megaclast or boulder size granitiods up to 4 m in diameter recorded by Diaz-Martinez et al. (1999), pebbles and cobble to a small granule size (1cm in diameter) that has been recorded by Bennett et al. (1996); Stern et al. (2006); Vesely and Assine (2014), refer (Figure 2.1). The existence of this dropstone also varies in type of rocks; data recorded by Kawai and Windly (2008) shows ice rafted dropstone are sandstone, chert and basalt and Che Aziz and Ibrahim (2003) record occurrence of granite, pegmatite quartzite, shale and limestone, while Diaz-Martinez et al. (1999) record a granitiods boulder in shales that were deposited by glaciomarine environment. It also can compositionally be dominated by granites, schists, quartz and green sandstone like the one recorded in Argentina by Limarino et al. (2014). Thus, the source of dropstone are not only limited to sedimentary rocks, it can be including sedimentary, igneous and metamorphic rock and not only restricted to glacier deposition Bennett et al. (1996); Korstgard and Nielsen (1989). Besides, glaciomarine dropstone clasts are recorded to have subangular to rounded sphericity and in some cases exhibit faceted surfaces and glacial striations on it surfaces (Limarino et al., 2014). Basically there are four main agents that control the dropstone transportation mechanism; ice rafting, biological rafting, floatation and projectiles. Here are several factors that contribute to the dropstone transportation and deposition:


Figure 2.1: The pictures of dropstone deposition and its variation in shape and size. Note that a man standing in front of a 6 meter diameter granite boulder in basal glaciogenic sediment in Ethiopia (Bussert, 2014).

### 2.1.1 Glaciers

According to Gaschnig et al. (2014) glacial diamictites classified as poorly sorted sedimentary aggregate derived from abrasion and erosion of bedrocks that are transported and deposited by the melting of ice. Glaciation naturally occurs in Mediterranean and polar region as it needs snow that were deposited in years to form glaciers. Due to the seasonal and climate changes, rise in temperature melt the glacier make it move as the gravitational forces pull it downwards. Moving glacier on a surface plucks away the source rocks and leave scour marks (Becq-Giraudon et al., 1996) (Figure 2.3). Deglaciation in mountain range will transport such debris flow and deposit it in the valley as gravity deposits preserved as “tillites”; clasts of angular and immediately proximal origin, indicating little transportation, Le Heron (2012) and this phenomena is called subglacial erosion product,  but if it is at coastal area it will float away drifted by the ocean currents, winds and tidal force (Vesely and Assine, 2014). Slowly ice rafts will melt into the ocean and deposits its load, or iceberg float away drifted and brings the rock fragment at the bottom part of it and discharge its load (Vesely and Assine, 2014). Thus, this rock fragment transported kilometers away from its origin and drops into a new host resembling the glaciomarine deposition mechanism (Liverman and Bell, 1996; Vesely and Assine, 2014), refer (Figure 2.2).

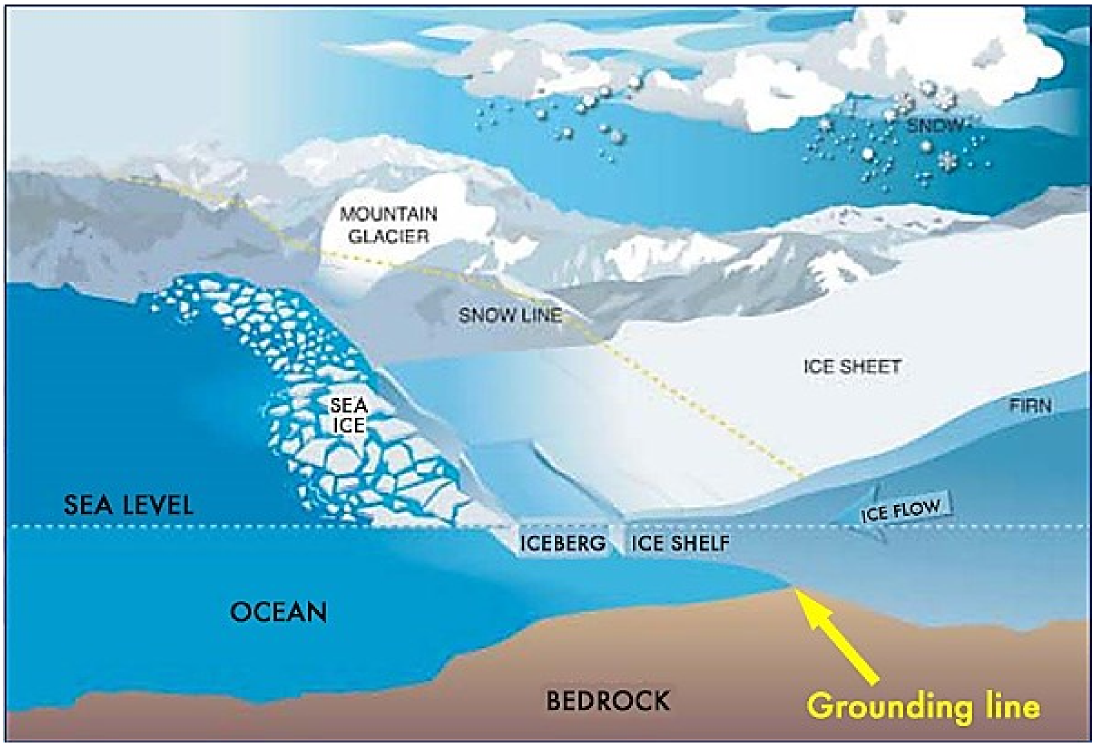


Figure 2.2: The summary of glaciation mechanism that were involved in Late Paleozoic Ice Age and depositional mechanism of dropstone in space.

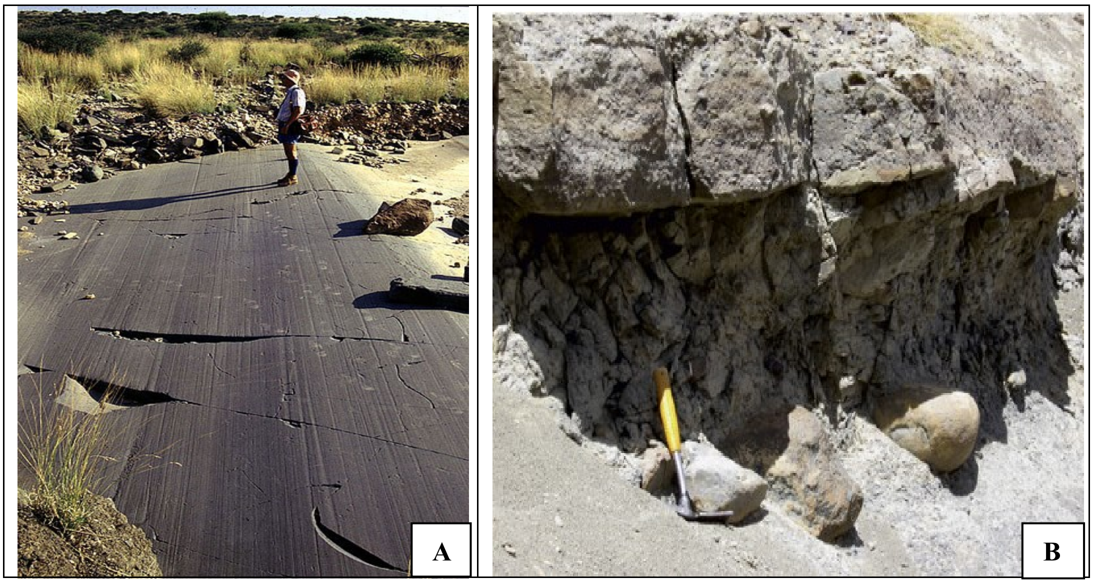


Figure 2.3: The ice keel scour marks left by striation of glacial movement, A and deposition of glacial megaclast dropstone in South Africa, B (Huber et al., 2001).

The most important key role to identify glaciomarine dropstone or diamictite deposits is by examining the deformation structure, which disturbs the primary structure of the facies. Such example of the laminated mudstone facies the laminar will be interrupted as the weight acting on it due to gravity driven force exerted on the soft sedimentary structure and produce what is called a draped structure. This deformational structure of soft sediments host rock can varies in degree of deformation, it depends on several factors that directly affect it during the depositional periods (Hladil, 1991). It can be caused by: 1. Sufficient water depth for stabilization of free fall motion of dropstone, which acquire in range of (1.2 – 7.5) meters water depth, 2. Factors that influence fall velocity oscillation, such as the "the coin effect" where frequently the position of clast fall will be on larger dimensions in horizon, 3. Significant bulk density of the dropstones, the relationship of density is directly proportional to kinetic energy, 4. Lateral water column force, such as currents, upwelling and downwelling could be neglected in the bottom water column, based on sedimentological evidence, 5. Neglecting the effect of water density and viscosity fluctuations which occur natural due to increasing depth of water column or by hydrostatic pressure by external force, 6. Resistance of sediment against deformational impact, which is related to the sediment composition, mainly grain sizes and early cementation during diagenesis, or degree of lithification and primary structure of sediments, 7. Dropstone is subjected to rework of sediment, where very intense sinking of clasts occur when the whole sediments is moved. Such structure used to be deep, laminae are often penetrated and sediment is irregularly deposited on the dropstone margin. 8. The degree of substrate lithification, which will give different draped structure on the host rock during the deposition of dropstone and their diagenesis. In illustration, refer (Figure 2.4) to see the different effect of deformational structure. 9. The function of dropstone diameter, D that was introduced to the substrate of host sediments that will affect the apparent depth of deformation and the size of draped structure around the dropstone itself.

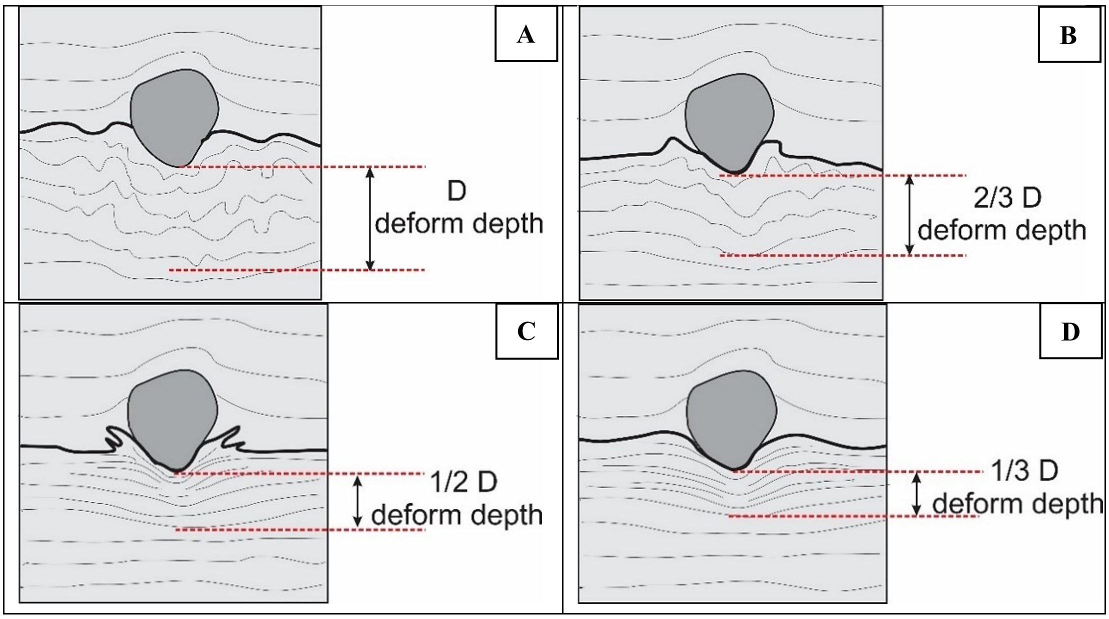


Figure 2.4: The deformational features (draped structure) from the impact of dropstone clast in host rock, which varies by substrates consolidation and constant in clast diameter. Note that the relationship of intensity and depth of deformation is inversely proportional to the substrate lithification, as a function of dropstone diameter, (D). A-Poorly consolidated substrate, the draped structure form circular wave crests. B-Slightly consolidated substrate draped forming one ridge structure. C-Moderately consolidate and viscous clay like substrate with thrust lips shape as draped. D-Very consolidated substrate with circular bulge draped structure.

### 2.1.2 Turbidity currents

Thin sand to clays interbedded structure with deformation bedding due to dropstone bearing sediments can be interpreted as turbiditic origin or glacio–turbidities deposits in the melt water around the glacier front (Vesely and Assine, 2014). Tectonics and earthquake motion usually triggers sediment movement downwards the continental slope in the ocean which makes turbidity currents happen. The potential difference due to the slope structure makes a sediment gravity flow that brings a denser current flow in the ocean. This strong ocean current flow can be one of the agents that brings rock fragment into finer sediment in Deep Ocean (Pindell, 1994).

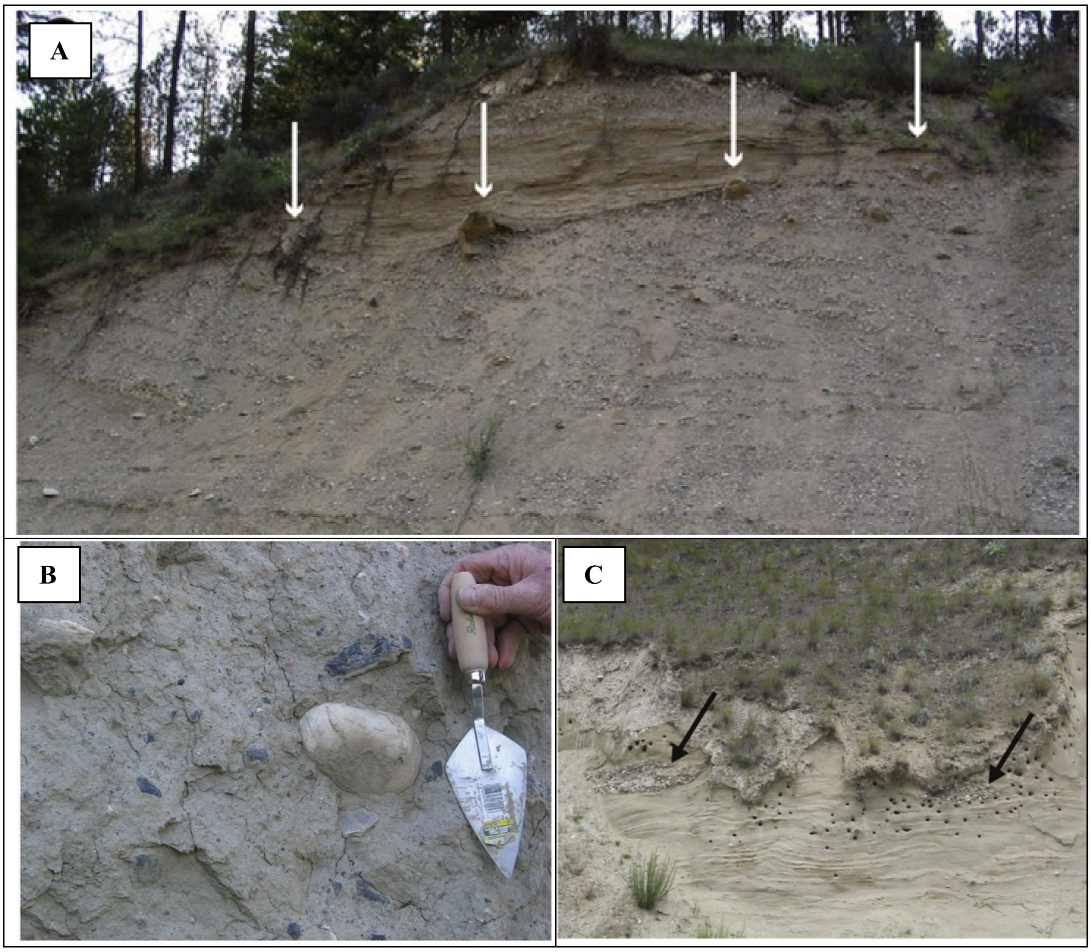

Figure 2.5: The pictures of Quaternary turbidites deposits in glacial Lake Columbia, Washington. A-Turbidites outcrop, arrow shows the dropstone clast. B-The matrix support clast, with poorly sorted clast inside mudstone C-Bedded and massive sand and silt containing ice-rafted gravel (arrows) (Hanson and Clague, 2016).