Libyan Journal of Science & Technology 11:1 (2020) 06–11

Faculty of Science - University of Benghazi

Libyan Journal of Science & Technology

journal home page: www.sc.uob.edu.ly/pages/page/77

# Transportation of sediments by floating processes from southern Europe to the coastal regions of eastern Libya: Pumice rock fragments from at Tariyah and Qasr Libya coasts

**Ashour Y. Elzouki and Omar B. Elfigih***

*Department of Earth Sciences, Faculty of Science, University of Benghazi, Benghazi-Libya*

## Highlights

- **The studied pumice samples (AT1 and QL1) from At Tariyah and Qasr Libya coasts are characterized by the volcanic glass with the possible intermediate origin and of unconnected vesicles that are likely to have stayed float for a longer time and prevent water-flow through the clasts.**
- **Pumice deposited on the eastern coast of Libya indicates that long-distance transport produces minimal or negligible changes in the textural parameters of floating load components.**
- **The source area for this material is believed to be the active volcanic regions in the east and south of Sicily of southern Italy.**

ARTICLE INFO

*Article history:*

Received 23 February 2020
Revised 01 April 2020
Accepted 03 April 2020

*Keywords:*

Pumice transportation, Floating processes, Coastal regions of eastern Libya, At Tariyah coast, Qasr-Libya coast.

**Address of correspondence:*

E-mail address: omar.elfigih@uob.edu.ly

O. B. Elfigih

ABSTRACT

Fragments of pumice of various sizes and roundness were found mixed with recent coastal sediments of calcareous sand, calcareous granules, and shells in At Tariyah coast southwest of Benghazi, and in the coastal area of Qasr-Libya, Al Jabal Al Akhdar, northeastern Libya. The source area for the pumice fragments appears to be the active volcanic regions of eastern and southern Sicily; Etna volcano and submarine volcano known as the CampiFlegrei del Mar di Sicilia respectively.

The pumice must have traveled a distance of at least 1000km across the Mediterranean Sea as a floating load.

The recent coastal sediments of the Al Jabal Al Akhdar area are derived mainly from two different sources; a southern proximal source consisting of a well-exposed sequence of Tertiary carbonate rocks that produced well-sorted sand-size fragments and a northern distal source that produced cobble-size fragments of pumice.

The mechanism of transporting sediments by floating as a floating load, from one sedimentary basin to another is completely different from the other well-known and documented methods of bedload and suspended load. Floating fragments can be transported for long distances and finally deposited without appreciable changes in size, roundness, shape, or sorting. Pumice deposited on the eastern coast of Libya indicates that long-distance transport produces minimal or negligible changes in the textural parameters of floating load components.

## 1. Introduction

This paper discusses the occurrence of extra-formational clasts of pumice found admixed with the recent calcareous beach sands and coastal sediments of Al Jabal AL Akhdar in northeastern Libya. Pumice is evidently of extraneous origin as virtually all of the volcanic rocks of Libya are of mafic composition. The area of study lies on the eastern coast of Libya; specifically in At Tariyah coast southwest of Benghazi and in Qasr Libya coast north of Qasr Libya village (Fig.1). This study is aimed to document and describe the pumice fragments found in the study area and to define their possible sources and transportation mechanism along the coastal regions of eastern Libya.

## 2. Geologic setting

Al Jabal Al Akhdar consists mainly of carbonate rocks sequence of Upper Cretaceous to Miocene age (Fig. 2). Details on the stratigraphy of Al Jabal Al Akhdar area can be found in Klen (1974), Rohlich (1974) and the field guide notes of El Hawat and Shelamani (1993), Elwerfalii *et al.* (2000), El Hawat and Abdulsamad (2004) and El Hawat and Pawellk (2005).

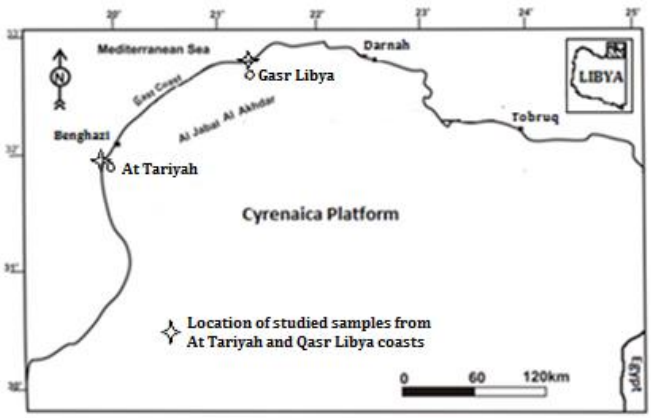


**Fig. 1.** Location map of the study area (At Tariyah and Qasr-Libya coasts), also showing the location of studied samples.

 ISSN 2663-1407; National Library of Libya, Legal number: 390/2018

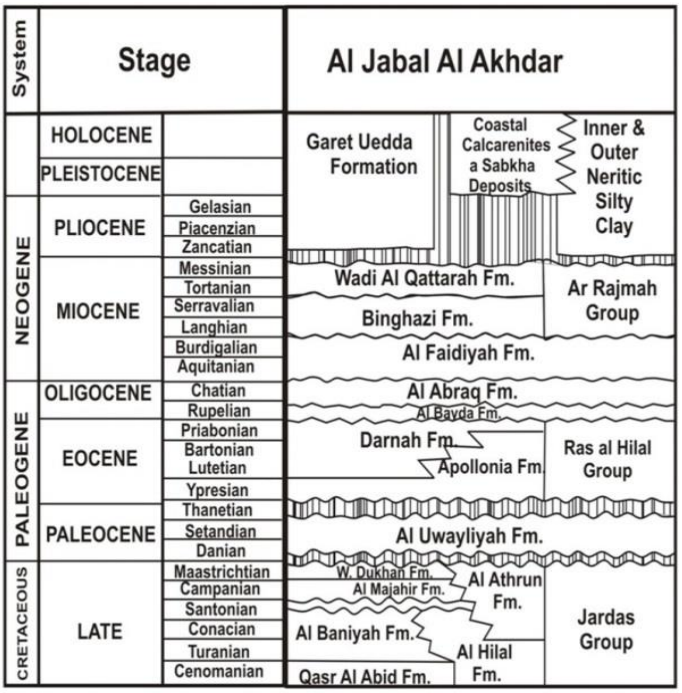


**Fig. 2.** Stratigraphy of Al Jabal Al Akhdar, (after El Hawat and Abdulsamad, 2004)

Quaternary and recent beach deposits (especially in the coastal area of At Tariyah and Qasr-Libya) are derived mainly from this carbonate rocks sequence and close to it; where these recent beach sand deposits are admixed with rudaceous volcanic clasts and are of yellowish to grayish, are largely composed of rounded, medium to coarse-grained detrital carbonate grains with abundant micro and macro shell fragments, with rare quartz grains.

Al Jabal Al Akhdar is an easterly to westerly trending anticlinorium that extends nearly parallel to the east coast (Fig. 3). The exposed rocks are of horizontal to semi-horizontal bedding, characterized by a regional low dip of about 2°-5° SW (Elfigih and Elgheriani, 2013, El Amawy *et al.* 2011). These rocks are well fractured, jointed and faulted at some places and characterized by two major regional fracture trends oriented NW-SE and NE-SW which may be attributed to tensional stresses associated with the formation of Al Jabal Al Akhdar (Elfigih and Elgheriani, 2013). According to Rohlich (1974; 1980), two different episodes of uplift occurred during Late Cretaceous to Late Miocene. Another possible minor trend of joints oriented E-W was also recognized, which might have contributed partially to the formation of the existent escarpment as a result of some compression and inversion tectonics in parts of Al Jabal Al Akhdar (Guiraud and Bosworth, 1999; Guiraud *et al.*, 2005). El Amawy *et al.* (2011) indicated that structural inversion during Late Cretaceous–Miocene times in response to a right-lateral compressional shear. The deformation within this system revealed three phases of tectonic stages during Late Cretaceous, Eocene, and Oligo-Miocene times.

## 3. Samples collection and description

The studied pumice samples (AT1 and QL1) were mostly collected from two coastal locations. The first is the At Tariyah area southwest of Benghazi and the second is the coastal area of Qasr Libya (Fig. 1). The pumice clasts are light grey, vesicular, and fall in cobble size (64 mm-256 mm). The vesicles are of an oval to rounded outline and various sizes. Samples collected from the two mentioned localities have an average length dimension of 150 mm. Pumice grains of sand and silt size may also occur in these areas. In general, the pumice clasts are rounded to subrounded (Powers, 1953) with oblate (disc) to equant (spherical-subspherical with broken edges) shapes (Zingg, 1935). The various degree of roundness here is attributed to the continuous and effective wave action following deposition of the clasts at shorelines (Fig. 4)

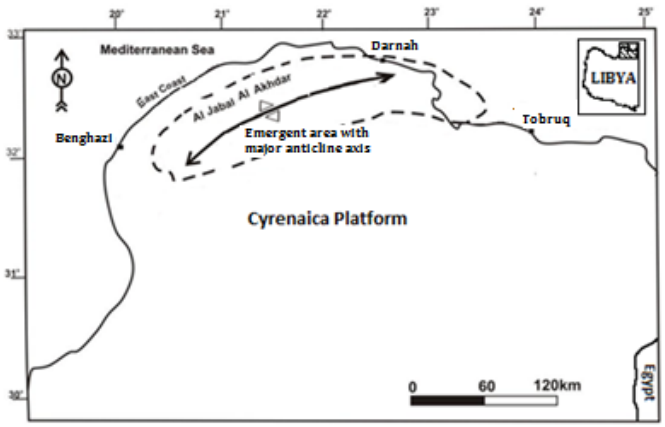


**Fig. 3.** Location map of Al Jabal Al Akhdar showing its emerged area with major anticline axis parallels to the east coast of Libya (modified after Rohlich, 1980).

## 4. Petrography

Petrographic observations of two pumice thin-section samples (AT1and QL1) from At Tariyah and Qasr Libya coasts respectively, impregnated with blue-dye epoxy resin have revealed that both samples are characterized by dark brown glassy quenched microcrystalline iron-rich matrix, with thick wall, undeformed, and unconnected vesicles, filled partially with aluminosilicate and quartz (Figs. 5 and 6, photomic 1, 3). The vesicle's size is ranging from 1mm to 5mm, with typically non-equant but rounded to subrounded morphology. The porosity of both samples is fair to good and the vesicles are poorly connected and filled by blue-dye epoxy (Figs. 5 and 6, photomic 2, 4). No fabric or preferred orientation could be seen from vesicle morphology or orientation. According to Klug and Cashman (1996), pumice clasts with well-formed spherical, unconnected vesicles, embedded in a brown glassy matrix, most likely originated from intermediate magmas of low viscosity. Moreover, the concentration of this iron-rich dark brown groundmass may represent variations in the eruption dynamics. Similarly, the studied pumice samples (AT1 and QL1) from At Tariyah and Qasr Libya coasts are characterized by the volcanic glass with the possible intermediate origin and of unconnected vesicles that are likely to have stayed float for a longer time and prevent water-flow through the clasts. The fact that all the examined pumice samples were found to display the same petrographic features, is significant. This indicates that the explosive eruption that would yield drift pumice is almost entirely the same.

## 5. Source area and transporting mechanism

As the entire exposed region of Al Jabal Al Akhdar is completely devoid of any type of igneous rock, the occurrence of volcanic clasts in the eastern coastal regions of Libya represents an extraordinary geologic occurrence that is worth to be discussed in regards to the source area and transportation mechanism. The active volcanic regions of southern Italy; such as Etna volcano of eastern Sicily and the submarine volcano is known as the CampiFlegrei del Mar di Sicilia southern of Sicily (Fig. 7), occur at a distance of 1000 to 1500 km across the Mediterranean Sea and northwest from the Al Jabal Al Akhdar region; these volcanic regions are the most likely source of pumice deposited on the eastern coast of Libya. Eroded and/or fallen pumice blocks and fragments reaching the sea must have been transported by floating (as floating load) by marine currents along the southerly to southeasterly directions (Fig. 8). In the Mediterranean Sea, water deficit is supplied by the inflow of the Atlantic water that flows from the Strait of Gibraltar eastward along the North African coast and enters the eastern basin through the Sicily Channel (Millot, 1999; Lascaratos *et al.*, 1999). The southern continental slopes of western and eastern basins are characterized by narrow and unstable (secondary path/recirculation) currents located in the Algerian (Algerian Current) and Levantine (Libya-Egyptian Current) sub-basins respectively, that flow from west to

east and lead to the generation of cyclonic and anticyclonic eddies (Mejdoub and Millot., 1995; Hamad *et al*., 2005; Taupier-Letage *et al*., 2007; Gerin *et al*., 2009). These currents extend as deep as the Levantine Intermediate Water (LIW) core depth (200–500 m) (Menna and Poulain, 2010).

Transport of the floating pumice clasts is essentially controlled by its specific gravity and its unconnected vesicles, regardless of the original size, shape, or distance of transport. Furthermore, the movement of the floating load is mainly governed by the velocity and direction of prevailing marine and/or wind currents.

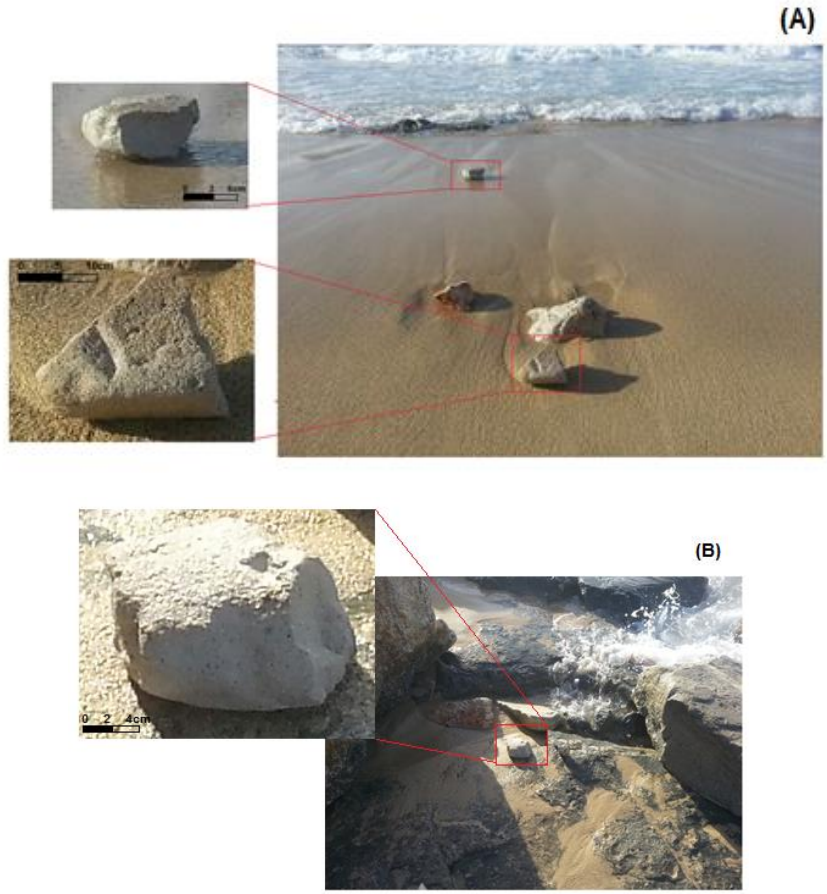


**Fig. 4.** Pumice rock fragments of various sizes and shapes with a vesicular texture (A: AT1- sample from the coast of At Tariyah, B: QL1-from the coast of Qasr Libya).

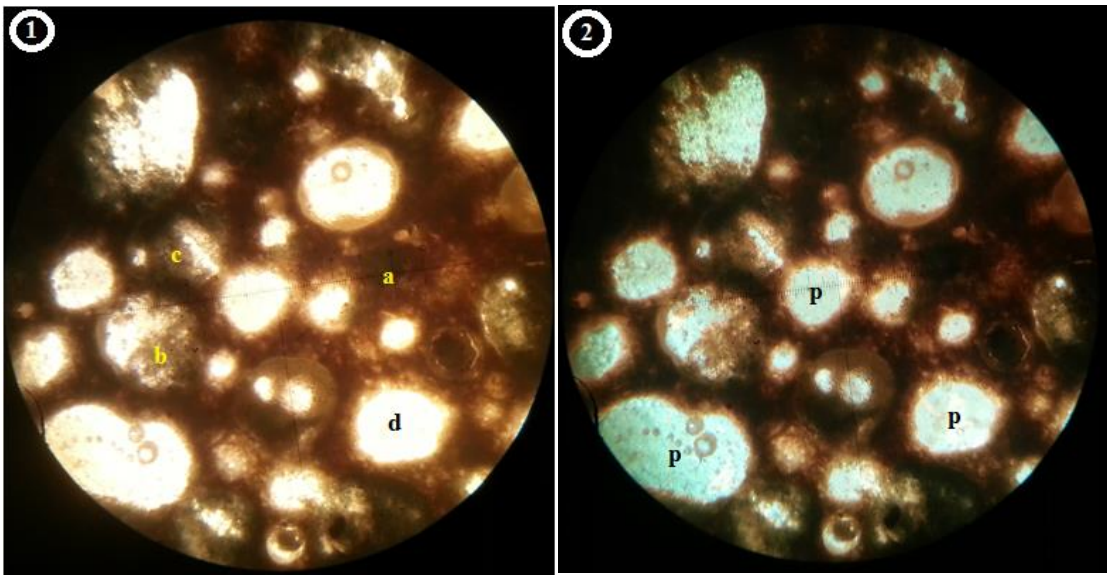


**Fig. 5.** Thin-section photomicrographs of sample **AT1** from At Tariyah coast showing: **in (photomicrograph1) at PPL:** a) Dark brown glassy microcrystalline iron-rich matrix, b) Aluminosilicate microcrystals partially filling vesicles, c) Quartz microcrystals, d) Rounded to subrounded vesicle. (Field of view 20 mm). **in (photomicrograph2) at XPL:** p) Poorly connected porosity as filled by blue-dye epoxy. (Field of view 20mm).

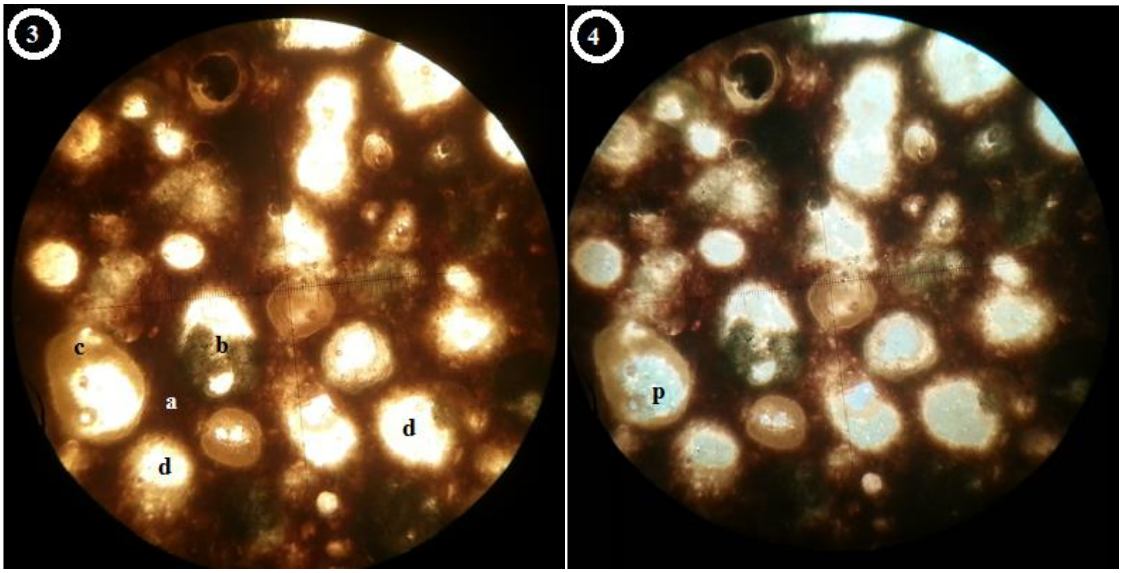


**Fig. 6.** Thin-section photomicrographs of sample **QL1** from Qasr Libya coast showing:**in (photomicrograph3) at PPL:** a) Dark brown glassy microcrystalline iron-rich matrix, b) Aluminosilicate microcrystals partially filling vesicles, c) Crystalline quartz fills, d) Rounded to subrounded vesicle with no preferred orientation. (Field of view 20 mm); **in (photomicrograph4) at XPL:** p) Poorly connected porosity as filled by blue-dye epoxy. (Field of view 20 mm).


**Fig. 7.** Map showing the location of Etna Volcano on the east coast of Sicily and CampiFlegrei Delmar di Sicilia Volcano on the south of Sicily (modified after Mediterranean_Sea_location_map.svg, 2016).


**Fig. 8.** Circulation of the Intermediate Water in the Mediterranean Sea (modified after Millot and Taupier-Letage, 2005).

The mechanism of transportation as a floating load from one sedimentary basin to another contrast sharply with the well-known and documented mechanism of bed traction and suspended loads (Selley, 1976). The established methods of sediment movement by rolling, creeping, saltation and suspension are controlled by some basic factors such as current velocity, competence, viscosity, the distance of transportation and the type of transporting medium as well as fragments original size and shape (Blatt *et al*. 1980; Dunbar and Rodgers, 1975; Middleton and southward, 1978; Selley, 1976). All of these factors, however, seem to have little or completely no influence on fragments that move without much mixing or collision by floating. Thus, it may be appropriate to classify the floating of such a load as the one discussed here as a new and different type of sediment transportation that can be added to the other previously mentioned methods (Fig. 9).

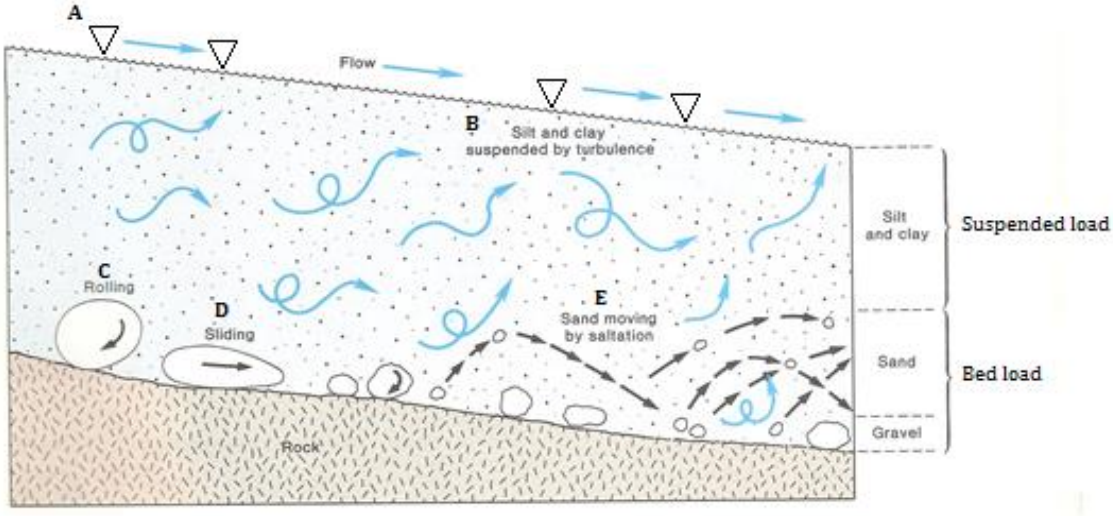


**Fig. 9.** Methods of particle movements: A) Floating, B) Suspended, C) Rolling, D) Sliding, E) Saltation "Bouncing" (modified after Selley, 1976; Plummer and McGeary, 1993).

## 6. Conclusions

In this study of pumice clasts from At Tariyah and Qasr Libya coasts, we find that these clasts are characterized petrographically by having well-formed spherical, unconnected vesicles, embedded in a brown-glassy matrix of possible intermediate magmas, which are likely to have stayed float for a longer time and prevent water-flow through them. However, the process of transportation of these clasts by floating for a long-distance requires a large dynamic aqueous medium, such as rivers, lakes, seas, and oceans. Floating fragments of different sizes and shapes can travel and be deposited in far-away sedimentary basins without appreciable change in their textural parameters. This process is somewhat analogous to transportation and deposition by glacial processes. In contrast, however, sediments transported by other methods usually show the effects of the distance of travel through changes in their textural parameters. In addition to the Tertiary carbonate component, the recent coastal beach sands of Al Jabal al Akhdar and southwest of Benghazi areas show a strong contribution of a distal source area represented mostly by extra-formational pumiceous material. The source area for this material is believed to be the active volcanic regions in the east and south of Sicily of southern Italy, as the eastern Mediterranean intermediate water currents have carried the pumice floating deposits along the southerly to southeasterly directions towards the eastern coast of Libya as evidenced in the studied areas of At Tariyah and Qasr Libya coasts. Although not abundant, this type of material may have a wider areal distribution over other Mediterranean regions.

## 7. Recommendations

Some suggested laboratory techniques are highly recommended such as; X-Ray Fluorescence Spectrophotometer (XRF) for determination of major elements, Scanning Electron Microscope (SEM) coupled with an Energy Dispersive Spectroscopy (EDS) are very well needed to assess vesicles (pore spaces) morphologies and to confirm details and gross mineralogical composition of pumice clasts identified in thin-section petrography. However, any further laboratory analysis is likely to necessitate more collection of samples to further investigate the compositional classification and the origin of these pumice clasts.

## Acknowledgments

The authors wish to thank the Department of Earth Sciences, Faculty of Science at the University of Benghazi for their encouragement and support to publish this paper. Special thanks and gratitude are expressed to Mr. Farag Moustafa, AGOCO Lab., Benghazi, Libya, for his assistance in preparing all thin-sections used in this study. Thanks are also extended to the anonymous reviewers for their constructive criticism of the manuscript.

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