DNIPRO UNIVERSITY of TECHNOLOGY 1899

Mining of Mineral Deposits
ISSN 2415-3443 (Online) | ISSN 2415-3435 (Print)
Journal homepage http://mining.in.ua
Volume 13 (2019), Issue 1, pp. 66-71

UDC 622.23.02 https://doi.org/10.33271/mining13.01.066

GEOLOGICAL FEATURES AND MARBLE PRODUCTION QUALITIES OF WESTERN TURKEY

M. Ozcelik[1*], Y. Leventeli[2]

[1]*Süleyman Demirel University, Isparta, Turkey*
[2]*Akdeniz University, Antalya, Turkey*
**Corresponding author: e-mail: ozcelikbakihan@gmail.com, tel. +902462111327*

ABSTRACT

Purpose. Isparta Angle occurs along the Mesozoic carbonate axis. Carbonated rocks forming the Taurus belt are continuous with allochthonous and autochthonous features. The rocks in the region are abnormally contacted with each other and can be found as allochthons on each other. The contacts between the tectono-stratigraphic units are commonly tectonic with the carbonate platforms forming the autochthonous basement to the west and east. For this reason, the initial relations between the rock masses and their initial geographical locations are not known.

Methods. Some of the carbonated rocks show similar characteristics to each other in terms of sedimentation environment, stratigraphic relations and some other characteristics; but they are separated from each other by different characteristics throughout the belt.

Findings. In this study, relationships between mass and material properties of marbles, which are produced in the allochthonous and autochthonous parts of the carbonated rocks in the western part of the Taurus belt, were investigated.

Originality. As a result of this study, it has been determined that the mass and material characteristics of autochthonous limestones are better in quality than those of allochthonous limestones.

Practical implications. Marble production qualities and block efficiency of allochthonous and autochthonous rocks have been evaluated.

Keywords: *carbonated rocks, marble production, mass and material properties, Taurus belt*

1. INTRODUCTION

Taurus Mountains form an important part of the Alpine orogenic belt that passes through the southern and eastern parts of Anatolia. The Isparta Angle, which was chosen as the study area, was formed by the reverse V-shaped bending of the carbonate axis forming the Taurus Mountains. The Isparta Angle has many different stratigraphic rock formations. Eğirdir-Kovada graben system separates the Isparta Angle as east and west. The rocks in the study area can be collected in two groups; allochthonous and autochthonous. The Mesozoic aged autochthonous Beydağları carbonate platforms and allochthonous Lycian nappes and Yavuz nappes in the region (Poisson, 1977; Poisson, 1984). In addition, all allochthonous and autochthonous units on the site are also known as the Antalya complex (Woodcock & Robertson, 1982; Robertson, 1993). In the eastern part of the Isparta Angle there are the Akseki-Anamas autochthonous carbonate platform and the Beyşehir-Hoyran ophiolitic nappes covering it tectonically (Poisson, 1984). On the other hand, in the western part of Isparta, there are autochthonous carbonates of Beydağları and Antalya nappes and Lycian nappe systems (Poisson, 1984; Robert-son & Woodcock, 1984).

The autochthonous carbonate rocks in the west of Isparta are defined as the Beydağları platform. The allochthonous rock assemblages of Antalya, Lycia and Beysehir-Hoyran ophiolitic nappes surround the autochthonous platforms of the region from the south, west and east. Marble deposits in the western Taurus belt and around the Isparta Angle are possible in two major groups as allochthonous and autochthonous in terms of geological location and formation conditions. The autochthonous beige marble de-posits on the Akseki-Anamas autochthonous carbonate platform and the Beydağları platform consist mainly of neritic carbonates with thick bedded broad-spread and very large reserves. Massive structured intercalations, mainly composed of reefal limestones, are commonly observed in autochthonous carbonate deposits. Carbonate structures consisting of labyrinth and melting voids are commonly found on the surfaces of autochthonous limestones. In addition to the widespread karstification, the multi-layered tendons affecting the autochthonous limestones and the associated shear failure and fracture systems are the leading factors directly affecting the marble production and block yield in the region. Allochthonous light beige marble beds are located in the ophiolitic rock communities known as the ophiolitic nappes of Antalya-Lycia and Beysehir-Hoyran in the region. The light beige marble beds in the allochthonous nap system are composed of mega-olistoliths with an ellipsoidal-shaped geometry, which can often be embedded in an autolithic matrix and more or less independent of each other.

2. REGIONAL GEOLOGY

The rocks formed in the Pre-Cambrian are exposed in the Western Taurus. Some of these rocks, which offer very different stratigraphic and structural features, are autochthonous and the other part is allochthonous (Fig. 1). The allochthonous rock communities in the region have been divided into three main groups (Poisson, 1984; Robertson & Woodcock, 1984) by previous researchers. These are Lycia, Antalya and Beysehir-Hoyran ophiolitic nappes from west to east. The Lycian nappes overlying the western part of Isparta Angle between the Middle-Late Eocene and Late Miocene settlement ages for the Beyşehir-Hoyran ophiolitic nappes on the eastern part are predicted. The Late Cretaceous-Early Palaeocene age was found suitable for the settlement of the Antalya nappes (Dilek & Rowland, 1993; Glover & Robertson, 1998a; Glover & Robertson, 1998b). However, the eastern part of the Isparta Angle formed by the main Akseki-Anamas autochthonous carbonate platform has undergone with a rotation of about 45 degrees clockwise since the Eocene (Poisson, 1984).

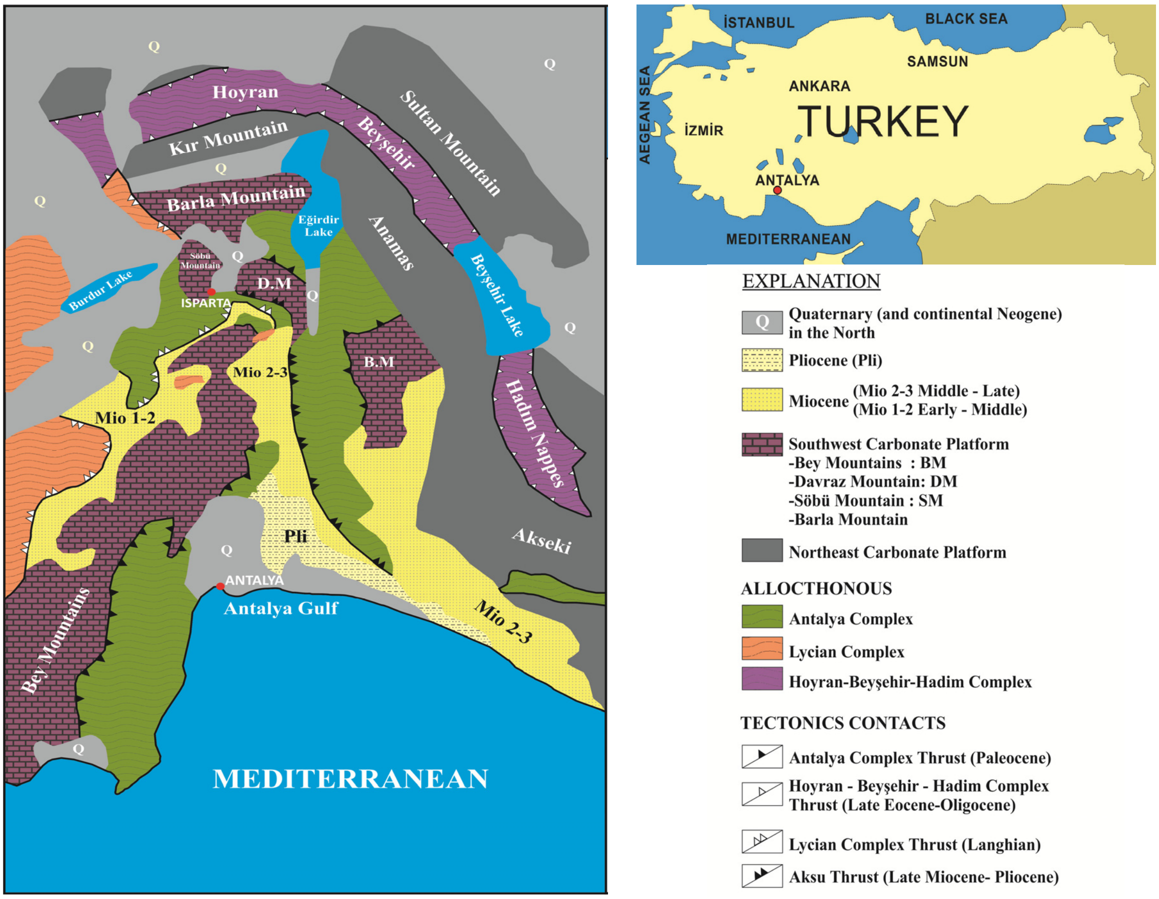

Figure 1. Geological map of the Western Taurus (Poisson, Yağmurlu, Bozcu, & Senturk, 2003)

2.1. Allochthonous units

The allochthonous units located in the study area are mainly according to settlement ages; (1) Antalya nappes settled during the Late-Early Palaeocene, (2) Yavuz nappes, which are a component of Lycian nappes, settled in the region during the Late Eocene-Late Miocene period.

2.2. Autochthonous units

The units in the research area are from top to bottom; Upper Cretaceous-Jurassic Beydağları Limestone, the Akitanian aged Yazır limestone showing reefal features, Isparta Çay Formation of Triassic aged Antalya nappe, Ağlasun Formation and Gölcük volcanic rocks.

3. TECTONIC FEATURES OF WESTERN TAURUS

The Eğirdir-Kovada graben system, which separates Isparta Angle as east and west direction, shows a symmetrical depression area characterized by two faults (Poisson, 1977; Poisson, 1984). Eğirdir-Kovada graben is approximately 75 km in the north-south direction. Although the northern part of Eğirdir Lake is 15 km in width, it decreases to 2 km in the south of Kovada Lake. It is observed that the graben is not continuing and damped in the southern part of Lake Kovada. Glover and Robertson (1998a, b) indicate that the faults dominate the cave graben, pre-dominantly NNW-SSE oriented, and that much of it is developed within the Mesozoic limestones.

The eastern and western parts of Eğirdir-Kovada graben are syntactic fault components which are parallel or semi-parallel to normal faults. North-South trending fault systems those are located between Isparta-Antalya and parallel to Eğirdir-Kovada graben (Yağmurlu, Savaşcın, & Ergun, 1995). The Antalya fault zone is formed in parallel to fault systems extending in the north-south direction with anechalon. The hyper alkaline volcanic outcrops located between Isparta and Antalya dominate these fault systems. Yağmurlu, Savaşcın, & Ergun (1995) emphasizes that the alkaline-hyper alkaline volcanic rocks in the north-south direction between Afyon and Antalya rejuvenate from north to south. On the other hand, the Kırkkavak fault, which is a component of the right oblique strike, is an important fault component parallel to the Eğirdir - Kovada graben to the east of the Isparta Angle (Poisson, Yağmurlu, Bozcu, & Senturk, 2003).

4. BLOCK PRODUCTION IN MARBLE QUARRIES

It can be used as a block marble if it is suitable in terms of colour and design in accordance with the standards in terms of engineering features and technological properties. It is necessary to know all the parameters in the marble field before the marble quarry is opened. Production planning should be made by using these parameters. Knowing the engineering and technological properties of the rock as a natural building block is a very easy process. However, the determination of the block sizes that can be taken from the marble quarry, the prediction of production, the orientation of the marble quarry requires more detailed engineering geology studies. In order for the rock mass in the field to be used as a block marble source; detailed field geology study, detailed discontinuity measurements and critical points should be drilled. Colour, pattern and tectonic features in terms of horizontal and vertical direction of changes in the very short distances in the marbles with positive results are not obtained from the surface studies.

Block marbles are produced by wire cutting method in the quarries. The main tools and machines that must be found in the quarries are; water tanks, marteaupiqueur, water hose, steel ropes, cables, switch sets, floodlight, fuel tanks, cutting machines, drilling machines, titano, rubber wheel loaders, generators, compressors. In the production with diamond wire, first of all cutting wire must be wrapped around the mass which will be cut and passed through it and turned by the flywheel of the wire cutting machine. In order to be able to do this, the drilling machine on the mass to be cut opens the holes generally 9 cm in diameter and water is used for cooling during drilling.

After the drilling machine has detected the hole piercing point, the machine is brought to that point and is inserted into the position to be in the vertical position, then fixed with the help of chains with special and adjustable apparatuses on the four sides. In these fixing processes, special chambers are used which are embedded in the rock mass. These chambers are to be pierced and reinforced. The drilling machine fixed at the place is finely adjusted by using the adjustment apparatuses on the chains and is made full vertical again and drilling is started. After the vertical hole operation is completed, horizontal drilling operations are performed by bringing the drilling machine to the fully horizontal position. Horizontal and vertical holes must overlap each other so that the wire cutting method can be applied and the circumference of the mass to be cut is completely wrapped around. Various auxiliary tools such as laser, theodolite, water balance and plumbing are used to ensure that the drilling machine coincides with the two drilled holes. After the holes are joined, the process of passing the diamond wire through these holes begins. A guiding rope is used for this.

A very light material (cotton, fungus, etc.) that is connected to the tip of the guide rope is brought to the mouth of one of the holes and pressurized air is supplied here. With the effect of the pressurized air, the light material enters through the hole and exits from the other hole. The outgoing guide is pulled by connecting a diamond wire. Thus, the preparations for the cutting operation are completed (Kun, 2000). Titano or air cushion is used to separate the cut block from the main rock. The blocks separated from the main rock are subjected to a second cut by the censoring process. After the cutting process, the blocks are shipped to the block stock area.

5. MARBLE PRODUCTION QUALITIES AND BLOCK EFFICIENCY

Since the wire cutting machine cannot perform the cutting process, intra-operational levels negatively affect marble quality and block productivity. Karstic structures composed of solution voids are commonly found on the surfaces of autochthonous limestones. There are too many karstic cavities in the areas where frequent fractures and cracks are observed (Fig. 2). In addition, the factor affecting marble production and block productivity are karstification, over thrust affecting the autochthonous limestones, shear failure, fracture systems.

Figure 2. Karstic structure which negatively affects block production

The abundance of fractures and cracked surfaces, the presence of silica concentrations, and the intensive observation of intraformational levels affect the block production, negatively (Figs. 3, 4). Allochthonous light beige marble deposits are located within the ophiolitic rock assemblages known as the Antalya-Lycia and Beyşehir-Hoyran ophiolitic nappes in south western Anatolia (Fig. 5).

Figure 3. Block production has been affected by fractured karstic surfaces negatively

Figure 4. Rough surfaces also affect block production poorly

The light beige marble deposits in allochthonous nap systems consist of mega-olistoliths with an ellipsoidal-shaped geometry (Fig. 6), which are generally embedded in an autolithic matrix and are more or less independent of each other. In addition, the block yield may vary in some quarries where the pattern and colour homogeneity is somewhat deteriorated. Laboratory tests were carried out on the rock samples to determine the engineering properties of the selected marbles.

Figure 5. Appearance of ophiolitic rock assemblages near the quarry

Figure 6. The appearance of the marble quarry opened in Mega olistoliths

The tests on tensile strength NX size specimens were performed according to the procedures recommended by ISRM (1981). The laboratory testing programme comprised the determination of natural unit weight, water saturation, porosity, uniaxial compressive strength, Los Angeles abrasion loss. Test results are summarised and presented in Table 1.

Table 1. Engineering properties of the selected marbles

Sample	Hardness, Mohs	Natural unit weight, kN/m^3	Water saturation (mass), %	Water saturation (volume), %	Porosity, %	Uniaxial compressive strength, MPa	Los Angeles abrasion loss, % 500 Rev.
Burdur Beige	4.5	26.7	0.10	0.40	0.40	112.0	14.70
Burdur Brown	3.0 – 4.0	27.0	0.20	0.60	0.60	101.9	16.70
Karia Korkuteli Beige	4.0 – 5.0	27.4	—	0.48	0.47	102.0	—
Lykia Burdur Beige	4.0 – 4.5	27.0	0.07	0.19	0.19	115.2	25.93
Toros Korkuteli Beige	4.0	26.9	0.20	0.50	0.50	141.0	15.27
Bucak White Travertine	3.5	25.1	0.80	2.10	2.10	65.0	36.03
Antalya Limestone	3.5	23.7	3.50	8.20	8.20	45.0	47.50
Sütçüler I Beige	3.5 – 4.0	25.5	2.80	7.35	8.64	936.8	25.50
Sütçüler II Beige	3.5 – 4.0	28.0	0.60	1.67	1.12	905.5	21.70

6. RESULTS AND DISCUSSION

The geological and engineering geological studies to be carried out before the block production process on the marble quarries will make the field better known. Production losses will be reduced by determining the appropriate pro-duction pattern in accordance with these studies. The followings are the steps to increase the production efficiency:

Detailed topographic and geological maps of the site should be prepared for each quarry.

Necessary stratigraphic measurements should be made in the field. If there are karstified and filled zones in the study area, distribution patterns should be determined in stratigraphy studies.

Field observations and laboratory studies should be done according to facies definition.

Stratigraphic studies and facies definitions provide to the continuity of the best produced marble levels and contribute to plan the production of the quarry correctly.

Within the context of tectonic studies, the fracture and fracture directions of the area must be specified by making necessary measurements from the fractured and cracked surfaces. Crack systems should be transferred to various programs on the computer to determine the ideal block sizes that can be produced at the site. In order to increase the yield of blocks during operation, it is necessary to cut perpendicular to the dominant cracks and fracture surfaces.

Engineering geological tests and chemical analyses should be carried out on the samples taken from the field and the marble which will be produced according to the obtained results should be determined according to the national and international standards and the usage areas of marble should be indicated.

Considering the geological, stratigraphic and engineering geological parameters, the ideal production and operation model for open pits should be put forward in terms of the calculated reserve potential.

7. CONCLUSIONS

It is possible to collect marble deposits in the western Taurus belt and in the vicinity of Isparta Angle in two main groups, allochthonous and autochthonous in terms of geological location and formation conditions. The Tertiary aged sedimentary and volcanic rock units, especially the Mesozoic carbonate rocks in Isparta Angle, are accompanied by autochthonous units. On the other hand, the ophiolites in the region and the accompanying pelagic rock assemblages bring allochthonous units to the site. The geological and engineering geological studies to be carried out before the block production process on the marble quarries will be made better recognition of the field. Production losses will be reduced by determining the appropriate production pattern in accordance with these studies. Marble blocks are produced by wire cutting method. In addition to the widespread karstification in the Western Taurus, multi-layered over thrust affecting the autochthonous limestones and the associated shear fault and fracture systems are the leading factors directly affecting the marble production and block yield in the region. The light beige marble deposits in the allochthonous nap system are composed of mega-olistoliths with an ellipsoidal shaped geometry, which can often be embedded in an ophiolitic matrix and more or less independent of each other. In some quarries where the pattern and colour homogeneity is somewhat deteriorated, the block yield may vary.

ACKNOWLEDGEMENTS

The authors would like to thank the anonymous reviewers for their valuable comments and suggestions to improve the quality of the paper. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

Dilek, Y., & Rowland, J. (1993). Evolution of conjugate passive margin pairs in Mesozoic Southern Turkey. *Tectonics*, (12), 954-970. https://doi.org/10.1029/93TC01060

Glover, C.P., & Robertson, A.H.F. (1998a). Role of regional extension and uplift in the Plio-Pleistocene evolution of the Aksu Basin, SW Turkey. *Geological Society London*, (155), 365-387. https://doi.org/10.1144/gsjgs.155.2.0365

Glover, C.P., & Robertson, A.H.F. (1998b). Neotectonic intersection of the Aegean and Cyprus tectonic arcs: extensional and strike-slip faulting in the Isparta Angle, SW Turkey, *Tectonophysics*, (298), 103-132. https://doi.org/10.1016/S0040-1951(98)00180-2

ISRM (International Society for Rock Mechanics). (1981). *Rock characterization, testing and monitoring: ISRM suggested methods*. Oxford, United Kingdom: Pergamont Press.

Kun, N. (2000). *Marble geology and technology*. İzmir, Turkey: Dokuz Eylül University Press.

Poisson, A. (1977). *Recherches geologiques dans les Taurides occidentales (Turquie)*. Orsay, France: Université Paris-Sud.

Poisson, A. (1984). The extension of the Ionian Trough into southwestern Turkey. *Geological Evolution of the Eastern Mediterranean. Geological Society Special Publication*, (17), 241-250. https://doi.org/10.1144/gsl.sp.1984.017.01.18

Poisson, A., Yağmurlu, F., Bozcu, M., & Senturk, M. (2003). New insights on the tectonic setting and evolution around the apex of the Isparta Angle (SW Turkey). *Geological Journal*, (38), 257-282. https://doi.org/10.1002/gj.955

Robertson, A.H.F., & Woodcock, N.H. (1984). The SW segment of the Antalya complex, Turkey, as a Tethyan Mesozoic-Tertiary continental margin. *Geological Society, London, Special Publication*, *17*(1), 251-271. https://doi.org/10.1144/gsl.sp.1984.017.01.19

Robertson, A.H.F. (1993). Mesozoic-Tertiary sedimentary and tectonic evolution of Neotethyan carbonate platforms, margins and small ocean basins in the Antalya Complex, southwest Turkey. *Special Publication of International Association of Sedimentology*, (20), 415-465.

Woodcock, N.H., & Robertson, A.H.F. (1982). Wrench and thrust tectonics along a Mesozoic-Cenozoic continental margin: Antalya Complex, SW Turkey. *Journal of Geological Society of London*, *139*(2), 147-163. https://doi.org/10.1144/gsjgs.139.2.0147

Yağmurlu, F., Savaşcın, Y., & Ergun, M. (1995). Relation of alkaline volcanism and active tectonism within the evolution of Isparta Bend, SW-Turkey. *The Journal of Geology*, *105*(6), 717-728. https://doi.org/doi:10.1086/515978

ОСОБЛИВОСТІ ГЕОЛОГІЧНОЇ БУДОВИ ТА ВИДОБУТКУ БЛОКОВОГО МАРМУРУ В ЗАХІДНІЙ ТУРЕЧЧИНІ

М. Озцелік, Я. Левентелі

Мета. Виявлення геологічних особливостей залягання і властивостей автохтонних та алохтонних карбонатних порід Західної Туреччини для можливості їх промислового освоєння.

Методика. Аналіз геологічної й тектонічної карт Південно-Західної Туреччини для вивчення стратиграфічних і структурних особливостей автохтонних та алохтонних карбонатних порід. Досліджено фізико-механічні властивості карбонатних порід Таврського поясу. Міцність зразків на розтяг були виконані відповідно до процедур, рекомендованих ISRM. Програма лабораторних випробувань включала визначення природної маси одиниці, водонасиченості, пористості, міцності на одноосьове стиснення, втрати на стирання.

Результати. Відзначено, що у Таврському поясі карстифікація і багатошарові надвиги, що впливають на автохтонні вапняки й пов'язані з ними системи розломів і тріщин зсуву, є провідними факторами, які безпосередньо впливають на виробництво мармуру та вихід блоків у регіоні. Надана кількісна оцінка фізико-механічним властивостями алохтонних та автохтонних карбонатних порід. Акцентується увага щодо необхідності вимірювання на поверхнях порід системи тріщинуватості й за допомогою комп'ютерної обробки визначення ідеальних розмірів блоків у процесі видобутку. Встановлено, що для збільшення виходу блоків під час роботи їх необхідно різати перпендикулярно домінуючим тріщинам і поверхням руйнування. Рекомендується всі необхідні стратиграфічні вимірювання проводити у польових умовах і в разі, якщо у досліджуваній зоні є карстифіковані й заповнені зони, вони повинні бути враховані у стратиграфічних картах і розрізах.

Наукова новизна. Для умов Таврського поясу встановлено, що масові та матеріальні характеристики автохтонних вапняків перевершують за якістю характеристики алохтонних вапняків, і вони можуть розглядатися як першочергові родовища для видобутку блочного каменю відкритим способом.

Практична значимість. Проведення інженерно-геологічних робіт до процесу видобутку мармурового блочного каменю дозволить уточнити запаси й підвищити привабливість родовища до освоєння, а також знизити майбутні виробничі витрати шляхом визначення необхідної структури виробництва відповідно до даних досліджень.

Ключові слова: *карбонатні породи, видобуток мармуру, масові та матеріальні характеристики, Таврський пояс*

ОСОБЕННОСТИ ГЕОЛОГИЧЕСКОГО СТРОЕНИЯ И ДОБЫЧИ БЛОЧНОГО МРАМОРА В ЗАПАДНОЙ ТУРЦИИ

М. Озцелик, Я. Левентели

Цель. Выявление геологических особенностей залегания и свойств автохтонных и аллохтонных карбонатных пород Западной Турции для возможности их промышленного освоения.

Методика. Анализ геологической и тектонической карт Юго-Западной Турции для изучения стратиграфических и структурных особенностей автохтонных и аллохтонных карбонатных пород. Исследованы физико-механические свойства карбонатных пород Таврского пояса. Прочность образцов на растяжение были выполнены в соответствии с процедурами, рекомендованными ISRM. Программа лабораторных испытаний включала определение естественной массы единицы, водонасыщенности, пористости, прочности на одноосное сжатие, потери на истирание.

Результаты. Отмечено, что в Таврском поясе карстификация и многослойные надвиги, воздействующие на автохтонные известняки и связанные с ними системы разломов и трещин сдвига, являются ведущими факторами, непосредственно влияющими на производство мрамора и выход блоков в регионе. Дана количественная оценка физико-механическим свойствам аллохтонных и автохтонных карбонатных пород. Акцентируется внимание о необходимости измерения на поверхностях пород системы трещиноватости и при помощи компьютерной обработки определения идеальных размеров блоков в процессе добычи. Установлено, что для увеличения выхода блоков во время работы их необходимо резать перпендикулярно доминирующим трещинам и поверхностям разрушения. Рекомендуется все необходимые стратиграфические измерения производить в полевых условиях и в случае, если в исследуемой зоне имеются карстифицированные и заполненные зоны, они должны быть учтены в стратиграфических картах и разрезах.

Научная новизна. Для условий Таврского пояса установлено, что массовые и материальные характеристики автохтонных известняков превосходят по качеству характеристики аллохтонных известняков, и они могут рассматриваться как первоочередные месторождения для добычи блочного камня открытым способом.

Практическая значимость. Проведение инженерно-геологических работ до процесса добычи мраморного блочного камня позволит уточнить запасы и повысить привлекательность месторождения к освоению, а также снизить будущие производственные потери путем определения подходящей структуры производства в соответствии с данными исследованиями.

Ключевые слова: *карбонатные породы, добыча мрамора, массовые и материальные характеристики, Таврский пояс*

ARTICLE INFO

Received: 14 November 2018
Accepted: 4 February 2019
Available online: 11 February 2019

ABOUT AUTHORS

Mehmet Ozcelik, Doctor of Philosophy, Associate Professor of the Department of Geological Engineering, Süleyman Demirel University, Batı Campus, 32260, Isparta, Turkey. E-mail: ozcelikmehmet@sdu.edu.tr

Yasemin Leventeli, Doctor of Philosophy, Assistant Professor of the Department of Geological Engineering, Akdeniz University, Dumlupinar Bulvari, 07058, Antalya, Turkey. E-mail: leventeli@akdeniz.edu.tr