The Deformation Responses As The Resulted Of The Tectonics In Apaumagida (Apowo), Enarotali And Legare Mountain Area of Papua Province

[1]*Maran Gultom, [2]Doodle Dandy Waromi, [3] Mirzam Abdurrachman, [4]Iwan Yaner Ayomi , [5]Yafet Steven Wetipo, [6]Ela Disti Mambrasar

Coresponden author:
Email: **gultommaran@gmail.com**

[1,2,4,5,6]Univeristas Ottow Geissler, Indonesia
[3]Institut Teknologi Bandung, Indonesia

Abstract
The deformation phenomenon in Central Mountain of Papua Province is very complex, isn't there the uniformity of geology structure pattern (folds, joints, faults) as resulted of tectonics or reactivations of the geology structure of the lately rock to the upper early rock?. Therefore, measuring the geology structure had to be done with the surface geological mapping and the measured section traverse in the field. The research area distributed in three boundaries of tectonics in coordinate 135° 00' 00" East - 136° 30' 00" East and 3° 00' 00" South - 4° 40' 00" South. There are three research areas namely the Apaumagida area represent the Permian – Triassic Periods in coordinate 135°18'11,88" East - 135°43'20,14" East and 3°56'17,59" South - 4°8'28,44" South, the Enarotali area represent the Cretaceous – Paleocene Periods in coordinate 136°18'45,08" East - 136°29'42,00" East and 3°53'34,75" South - 4°5'16,03" South, and the Legare Mountain area represent the Tertiary – Quaternary Periods in coordinate 135° 28' 54,87" East - 135° 47' 16,80" East and 3° 25' 31,17" South - 3° 6' 6,25" South. According to the result and discussion, conclusioned that the direction of folds, jonts, faults were different between the oldest periods to the youngest periods, indicated by the direction diffrent of principal stress on N 5° – 27°E in Permian Period, N 349° - 358°E in Triassic Period, N 15° – 32°E in Cretaceous period, N 45° 54° E in Paleocene Period, N52° – 74°E in Tertiary Period N74°-78° E in Quarternary. Therefore, there were general pattern in the diffrent of folds, joints and faults from Permian – Triassic and Cretaceous – Paleocene but there's conformity from the Tertiary – Quarternary. The general conclusion that the tectonic is actively roled for the geology structure developing in Central M.ountain area since Paleozoic to Quaternary.

Keywords: *Folds, joints, faults and principal stress.*

I. INTRODUCTION

The developing of geology Papua was headed by the New Guinea tectonic evolution since the oblique convergent between the Indo-Australia plate and the Pasific plate. Generally, The New Guinea and The Central Mountain were positioned by the type location of an active island arc subduction into beneath an active continental plate. (Hamilton, 1979; Dow, *et al*., 1988). This cases had proven from the lithology spreading, which the oceanic plate spreading such as the Creataceous – Tertiary Periods of the ophiolite complex and ultrabasic border on Derewo metamorphic rock (Dow, 1988). According to Sudradjat (2006), the metamorphic rock spreading consisted of the blue schist rocks is the transition zone when the oceanic plate rock subduction into the continental plate. Central part of the New Guinea divided into 4 lithotectonic province (Cloos, *at al.*, 2005) namely the New Guinea fore arc/fore arc basin (platform Arafura), the *central range* fold belt and thrust fault, Rufaer metamorphic belt and ophiolite belt, and subduction of the Melanesian archipelago arc complex likes the Meervlakte Depression / north coast basin and Mamberamo thrust fault belt (figure 1). To the south of the Derewo metamorphic rock spreaded the Central Mountain area with 1300 km in length

and 150 km in width belt as the rough tophography, a large part of the height more than 3000 m, most of the hills was arranged by the folds and the fauls.

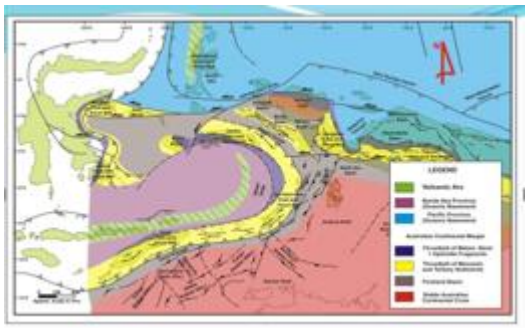

Fig 1. Map of the Eastern Indonesia tectonic frame (Modification by Barber, *et al*., 2003).

The geology hystory noted that the several times explotion of flora and fauna developing as long as the geological period and was followed contuously several *mass extinction*. research The tectonic deformation with used the Enarotali and Waghete geologic map sheets producted by The Center of Geology Developing and Researching Bandung in scale 1 : 250.000. (Figure 2**).**

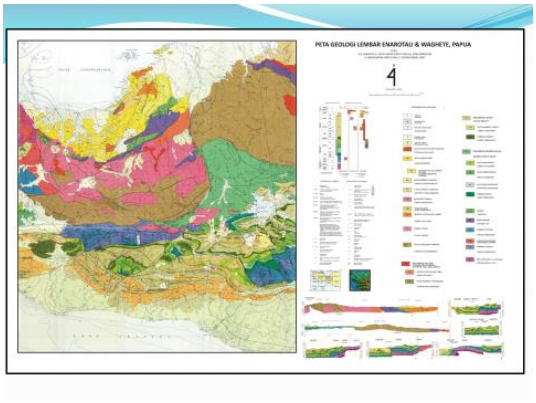

Fig 2. Geology map of the research area (Apaumagida, Enarotali dan Pegunungan Legare Papua)

That layering consisted of Paleozoic, Mesozoic sedimentation in border of the Australian continent plate (Cloos dkk, 2005). These width zone covered the thrust fault andfold subducted into the south consisted of Paleozoic rock up to the Early Cenozoic (Tertiary) from Australian continent. plate. To considered the research area as a nothern part of Australian plate, there are Tarera Aiduna fault from western to eastern, Lengguru fault from northen to southern and Waipoga Through and the end northern was intersectioned by Yapen fault. Those area was arranged by the lately rock (Permian) represented by Aiduna Formation gradually to the Early Qurternary rock. Folds and faults direction pattern is east – west up to north west – south east. These case as a structure phenomenon need to study more, isn.t it conformity of structure pattern (folds, joints, faults) as the tectonic response or structure reactivation of the lately rock to the upper early rock. Therefore, needed to studied, howfar the conformity of geological structure on older formation was compared to the above youngest rock. The deformation response of geological structure was realized into folds, joints, faults direction as same cases was need to studied more. Hopeful, to studied the geological structure response as a result of tectonic activities in the research area will open the tectonic rotation direction changing in research area. That geological phenomenon will be realized in the period boundaary namely between period : Lately Paleozoic – Early Mesozoic (Permian – Triassic) represent by Aiduna Formation and Tipuma Formation, boundary of Lately Mesozoic – Early Cretaceous (Tertiary/Paleocene) represented by Ekmai Formation and Waripi Formation, and boundary of Lately Cenozoic (Tertiary – Quarternary) represented by Konglomerat Karado and Batulumpur Bumi. Administratively, research area included

to Nabire Regency, Paniai Regency, Dogiyai Regency Papua Province. The three of research areas forms the western part of Papua Province lays on two the geological map sheets namely Enarotali map and Waghete map modificated into one geological map sheet ((figure 3) and the traverse map as shown.

II. METHODS AND MATERIALS

To prepared the tophographic map and drainages map of research area in scale 1:250.000 while the map will be shown scale 1: 100.000. The research object were data of folds, joints, faults from field and satellite image and airphotos. The used equipments were topographic map of Indonesia landscape map No . 3111 (Waghete sheet) and No. 3112 (Nabire sheet) with scale 1 : 25.000, producted by Bakosurtanal., GPS and geology compass, . satellite image SRTM, computere, *Software MapInfo* Professional Ver. 9.0 made by *Mapinfo Corporation* used for mapping, G*lobal mapper* Ver. 8 used for data and image SRTM processing , SPSS, XLSTAT 7.5.2 used for statistic data processing. Software Dips Ver. 5.1 prduced by *Rock Engineering Group*, *Departmen of Civil Engineering*, *University of Toronto*, used for identified the mean of geological structure elements

Rosette Diagram is one of the diagram model to presented the folds, joints, faults orientation into two dimensions. That principle was used the strike without dip of measuring data. Statistic test was used to knew the one factor is affected by or affected another factor (Sujana 2002). By the statistic test was used to normality, homogeneity, variance and different test (t-test). Normality test used as a *parametric test condition*, if data was normal, the *parametric test* can do (Sujana 2002). Normality test is one of data distribution normality test, forward to know one variable is normal or no. Normality test used by Liliefors test for the identificated significance level. Homogenity test used to check that data group comes from the homogenous population. Homogenity test of multyvariate variance-covariance used for sampel groups. Different test (t-test) used for check that comparing between independent variable, isn't it really diffrent or similar. At this test was compared value between t_{tabel} to t test.. To obtained the t test value: :

$$\overline{X_1} = \frac{\sum_{i=1}^{n1} X_{i1}}{n_1}$$

$$t = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\frac{{S_1}^2}{n_1} + \frac{{S_2}^2}{n1}}}$$

To obtain t_{tabel} used the equation :

$$t_{tabel} = \pm t_{\alpha/2(n1+n2-2)}$$

If $t_{test} < t_{tabel}$ there is no mean diffrent between the two independent samples, but if $t_{test} > t_{tabel}$ there is mean diffrent. By the diffrent test for mean of the sampels, can to identified the tectonic direction in research area. The principal stress direction can obtained by analisis of geological structure, namely the crack planes eg. folds, joints, faults will perpendicular to (σ1, σ3) plane or paralel σ2.

III. RUSULTS AND DISCUSSIONS

Objeck population in research area is boundary of Permian – Triassic Period represented by Aiduna Formation and Tipuma Formation , boundary Cretaceous – Paleocen repersentaed by Ekmai Formation and Waripi Formation, boundary Tertiary – Quarternary represented by Konglomerate Karado – Batulumpur Bumi. Result of research statistic test summaryzed at appendix 1.

The Boundary Deformation of Permian – Triassic Period in Apaumagida (Apowo) area

The selected area was Apaumagida area lays on the coordinate 135°18’11,88” E - 135°43’20,14” E and 3°56’17,59” LS - 4°8’28,44” S and administratively into Dogiyai Regency.

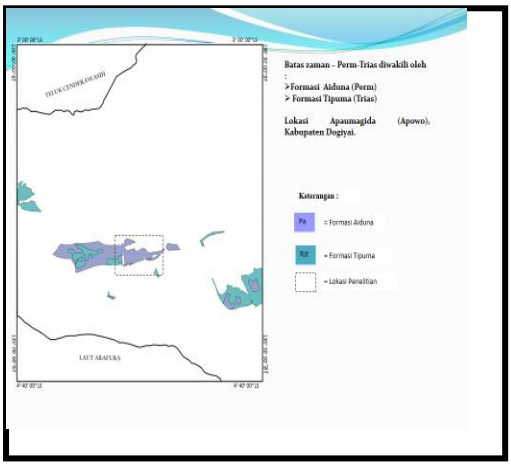

Fig 3. The Permian – Tiassic Period Boundary represented by Aiduna Formatin and Tipuma Formation in Apaumagida area Dogiyai Regency.

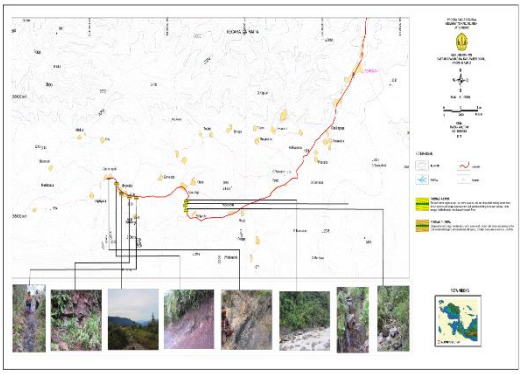

Figure 4. The traverse map in Apaumagida area

The Researching focused in several rivers eg. Mapia river, Pogi river, Pahau river.
The folds in Apaumagida area obtained from grid of geology map each 2 cm with scale 1: 25.000 to get the fold azimuth value.

The folds general pattern at Aiduna Formation and Tipuma Formation shown west – east direction. (figure 10). The joints data obtained from Aiduna Formation was shown south east – north west direction and Tipuma Formation was shown west- east direction.

The Boundary Deformation of Cretaceous – Tertiary Period (Paleocene) in Enarotali area

Enarotali area lays on 136°18’45,08” E - 136°29’42,00” E and 3°53’34,75” S - 4°5’16,03” S administravely into Paniai Regency. Folds formed at geological map with used the grid method per 2 cm in scale 1: 25.000 to obtained the azimuth. These folds formed anticline or syncline. The folds general pattern direction at Ekmai Formation is north west – south east and folds general pattern of Waripi Formation is noth west – south east.

The Boundary Deformation of Tertiary – Quarternary Period in Pegunungan Legare area

Pegunungan Legare area lays at 135° 28’ 54,87’’- 135° 47’ 16,80’’ E dan 3° 25’ 31,17’’- 3° 6’ 6,25’’S coordinate and administratively into Nabire Regency. The researching focused in several

rivers eg. Siriwini River, Nabire River and Araudo River Nabire Regency. Joints data at Konglamerat Karado is south east – north west direction and at Batulumpur Bumi is north – south. General pattern of faults developed in north –south and south weast – north east direction. Lateral dekstral faults with strike/dip $N175^0E/80^0$ and pitch 25^0 in north - south direction, this fault intersectioned the Batuan Gunungapi Nabire. The normal fault in south west – north east intersectionned the Batulumpur Bumi and Batuan Gunungapi Nabire.

The Hyphothesis Verification

Test of hyphothesis/subhyphothesis had been done to knewn the deformation response in Apaumagida (Apowo), Enarotali and Pegunugan legare areas forms the tectonic activities on folds, joints, faults variables.

The Boundary of Permian-Triassic Period

Deformation on Permian boundary obtained with the principal stress pattern of Central Mountain about N185,6° – 207,02°E affected to formed the folds, joints, faults pattern in Apaumagida (Apowo) and surrounded. Deformation on Triassic period obtained the principal stress N 167,13° – 178°E direction affected to formed the folds, joints, faults. By the geological structure elements description, boundary Permian – Triassic Period conclusioned that Permian tectonic period different to Triassic period indicated by different in folds, joints , faults pattern.

The Boundary of Cretaceous – Paleocene Period

The deformation direction in Cretaceous period N 185, 57° – 225,73° E afffected to formed folds, joints, faults. Direction of deformation in Early Tertiary Period (Paleocene) obtained the principal stress direction N192,38° – 240.47°E affeted to formed folds, joints, faults indicated there were strength tectonic more than in Aiduna Formation. By geologial structure description in boundary Cretaceous –Paleocen Period conclusioned that tectonic Cretaceous Period diffrent than tectonic Paleocene Period indicated by diffrent in folds, joints, faults pattern.

The boundary of Tertiary – Quarternary Period

The deformation direction in Lately Tertiary Period is N231,78° – 254,12°E which affected to formed the folds, joints, faults pattern. Deformation on Quarternary is N229,57° – 268,15°E principal stress direction in Pegunungan Legare area. There are evidences of geological structure elements in field to providing the tectonic indication more supported so that verification more reliable.

IV. CONCLUSIONS

The diffrent direction verification of folds, joints faults pattern in different boundary indicated by the direction different of principal strees at Permian Period N185,6° – 207,02°E, Trias Period N 167,13° – 178°E, Cretaceous Period N 185, 57° – 225,73° E Paleocene period N192,38° – 240.47°E Tertiary period N231,78° – 254,12°E dan Quarternary period N229,57° – 268,15°E. The principal stress different as resulted of evolution tectonic changing and Papuan tectonic rotation direction, since convergention of Australia, Karolin dan Pasifik plate likes *pure shear* model (without rotation) continued to the *simple shear* (with rotation). This research encouraged to answered that hyphothesis and sub-hyphothesis were appropriated for aimed to support the mineral and hydracarbon exploration, land resources and infrastructure development in Central Mountain Papua.

V. ACKNOWLEDGEMENTS

The authors would like to thank for Bapak Febri Hirnawan, Bapak Adjat Sudradjat, Bapak Dicky Muslim for supporting and councelling this research. To thank Bapak Safanpo Apollo and Bapak Janviter Manalu for kind attention.

REFERENCES

[1]. Anderson, E.M., 1951. The Dynamics of Faulting, dalam McClay, K.R. 1987. The Mapping of Geology Structures. Geological Society of London Handbook. ***John Wily&Sons, London***., p. 17 - 121

[2]. Andrew, I. Quarles van Ufford., 1996. Stratigraphy, structural geology and tectonics of a young forearc continent collision, western central Range , Irian Jaya (western New Guinea), Indonesia, Volume Two, Dissertation, Presented to the Faculty of Graduate School of The University of Texas at Austin in Partial Fulfillment of the Requirements for the Degree of Doctor Philosophy. ***The University of Texas at Austin. Austin***, Texas. USA., p 27 – 113.

[3]. A. Harahap, P. Hrp, N.K.A.R. Dewi, Macrozoobenthos diversity as anbioindicator of the water quality in the River Kualuh Labuhanbatu Utara, ***International Journal of Scientific & Technology Research***, 9(4), 2020, pp. 179-183.

[4]. Barber., Peter., Carter,f., Fraser, T., Baillie, Keith Myers, K. 2003. Paleozoic And Mesozoic Petroleum Systems In The Timor And Arafura Seas, Eastern Indonesia. Proceedings, Indonesian Petroleum Association, 29th Annual Convention And Exhibition, October 2003.

[5]. Sapie, B., Natawidjaya, DH & Cloos, M. Strike –slip Tectonics of New Gunea: Transform Motion Between the Caroline and Australian Plate. Proceedings of Indonesian of Geologists The 28th Annual Convention. Jakarta, Indonesia. 30 November – 1 O 1999.

[6]. Boggs, S. Jr.,2006., Principles of sedimentary and stratigraphy, Univesity of Oregon, fourth edition Upper Saddle River, New Yersey 07458, p. 406 -409, 572 -573.

[7]. Burollet, P. F. and C. L. Salle. 1985. Tectonic Significance Of The Banda Sea. Proceedings Indonesian Petroleum Association, 14th Annual Convention, October 1985.

[8]. Cloos, M, cs. 2005. Collisional delamination in New Guinea The Geotectonics of Subducting slab breakoff. Department of Geological Sciences University of Texas at Austin. Austin, Texas, USA.

[9]. Crowell, JC., 1984. Tectonics, sedimentation and structural analysis of basins, University of California, Santa Barbara, CA., 93106., USA., p. 7- 24.

[10]. Herman, D (Shell) & Sidi, FH (Conoco). 2000. An outline of The Geology of Indonesia. Riset Geologi dan Pertambangan Volume 19 No. I 2009., p.169 – 180.

[11]. Harahap, Arman ,2018, Macrozoobenthos diversity as bioindicator of water quality in the Bilah river, Rantauprapat, Medan. J. Phys.: Conf. Ser. 1116 052026.

[12]. Harahap, et, all, Macrozoobenthos diversity as anbioindicator of the water quality in the Sungai Kualuh Labuhanbatu Utara, AACL Bioflux, 2022, Vol 15, Issue 6.

[13]. Harahap, A. 2020. Species Composition & Ecology Index Of The Family Gobiidae At The Mangrove Belawan Of Sicanang Island ***International Journal of Scientific & Technology Research*** Volume 9, Issue 04, April 2020.

[14]. Harahap, A., et all (2021), Monitoring Of Macroinvertebrates Along Streams Of Bilah River ***International Journal of Conservation Sciencethis link is disabled***, 12(1), pp. 247–258.

[15]. Davis, George H. 1984. Structural Geology of Rock & Regions.John Wiley & Sons. New York, p. 65 – 85.

[16]. Doornkamp, C.C. 1986. Geomorfological Approaches to the Study of Neotectonics. Journal of the Geological Society, London, Vol. 143, pp. 335-342.

[17]. Dow, D.B., 1977. A geological synthesis of Papua New Guinea: Australian Bureau of Mineral resources, Geology and Geophysics Bulletin 201, 41.

[18]. Dow, D.B., and Sukamto, R. 1984. Late Tertiary to Quarternary tectonics of Irian Jaya: Episodes, v.7, p.3-7.

[19]. Dow, D.B., Robinson, G., P Hartono, U., and Ratman, N., 1986. Geologic map of Irian Jaya, Indonesia. Geological Research and Development Centre, Indonesian Ministry of Mines and Energy, scale 1 : 1.000.000, 2 sheets. Bandung, Indonesia.

[20]. Dow, D.B., Robinson, G., P Hartono, U., and Ratman, N., 1988. Geology of Irian Jaya: Geological Research and Development Centre, Indonesia.

[21]. Dow, D.B., Robinson, G., P Hartono, U., and Ratman, N., 1988. Geology of Irian Jaya: Irian Jaya Geological Mapping Project, Geological Research and Development Centre, Indonesia, in cooperation with the Bureau of Mineral Resources, Australia, on Behalf of Department of Mines and Energy, Indonesia, and Australian Develompment Assistance Bureau, 298 p.

[22]. Dow, D. B., Harahap, B. H., and Sufni, H.A., 1990. Geology of the Enarotali sheet area, Irian Jaya: Geological Research and Development Centre, Department of Mines and Energy. Bandung, Indonesia. scale 1 : 250.000 , 1 sheet, 57 p.
[23]. Fleuty, M.J., 1964. The Description of Fold, dalam Ragan, Donal M. 1984. Structural Geology: An Introduction to Geometrical Techniques Third Edition. John Wiley & Sons, Inc. New York.
[24]. Gultom, M., 2011, Response of Deformation, Dynamic of Transgression–Regresion, and Tectonic Geomorphology in Apaumagida (Apowo), Enarotali and Pegunungan Legare area due to tectonic Papua, Dysertasion, Program of Postgraduate Padjadjaran University, Bandung
[25]. Hall, R. 2003. Cenozoikum Tectonics Of Indonesia. Short Course IPA.
[26]. Hall, R. and M. E. J. Wilson. 2000. Neogene Sutures in Eastern Indonesia. SE Asia Research Group, Department of Geology, Royal Holloway University of London, UK. Journal Of Asian Earth Sciences 18 (2000) 781-808, 28p.
[27]. Hamilton, W., 1979. Tectonics of the Indonesian region: U.S Geological Survey Professional Paper, 345 p.
[28]. Harding, T.P. 1974. Petroleum Traps Associated with Wrench Faults: AAPG Bull., v. 58, Hal. 1290-1304.
[29]. Hancock, P. 1992. Continental Deformation, ***Journal of Structural Geology***., p. 370 – 409.
[30]. Hills, R & Scott Reynolds. The Australian Stress Map. National Centre for Petroleum Geology and Geophysics Australia Petroleum Cooperati Research Center.
[31]. Hirnawan, F. 2007, Riset, bergulirlah Proses Ilmiah, menuju penemuan baru dan orisinil, Guru Besar Geologi Universitas Padjadjaran, Unpad Press, Bandung.
[32]. .Busono, I & Alam, H., 1999. Developments in Indonesian Tectonics and Structural Geology, Proceeding of Indonesian Association of Geologists Volume I The 28h Annual Convention, Jakarta, Indonesia.
[33]. Mandl, Georg. 2005. Rock Joints The Mechanical Genensis. Springer Veerlag Berlin Heidelberg. New York.
[34]. Park, 1986., Foundation of structural geology.
[35]. Permana, H., Suharyanto, A., Soebandrio & R. Soeria Atmadja., Evidence of Cenozoic Tectonics: Implication to Basement Evolution and Configuration of the Northern Part of Irian Jaya, Proceedings of Indonesian of Geologists The 28 th Annual Convention, Jakarta , Indonesia, 30 November – 1 Desember 1999.
[36]. Pigram, C. J., and Panggabean, H.. 1989. Geology of the Waghete sheet area, Irian Jaya: Geological Research and Development Centre, Department of Mines and Energy, Bandung, Indonesia, scale 1 : 250.000 , 1 sheet, 46 p.
[37]. Prabawati A. 2010. Mengolah Data Statistik Hasil Penelitian Dengan Spss 17. Penerbit: C.V Andi Ofset Yogyakarta.
[38]. Price, N. J. And J. W. Cosgrove. 1990. Analysis of Geological Structures. Cambridge University Press. Cambridge, New York.
[39]. Ragan, Donal M., 1984. Structural Geology: An Introduction to Geometrical Techniques Third Edition. John Wiley & Sons, Inc. New York.
[40]. Setia Pratama, A., Sudarmiatin, S., & Wishnu Wardhana, L. (2023). The Influence Of Product Perceived Quality, Service, Environment And Assortment On Customer Loyalty With Customer Satisfaction As An Intervening Variable In Angkringan UMKM In Mojokerto Regency. *International* ***Journal of Science, Technology & Management,*** *4*(6), 1420-1432. https://doi.org/10.46729/ijstm.v4i6.978.
[41]. Evanthi, A., & Mukti Azhar, R. (2023). Planning and Implementation of Event Marketing in Sociopreneurship . ***International Journal of Science, Technology & Management***, *4*(6), 1451-1459. https://doi.org/10.46729/ijstm.v4i6.1003.
[42]. Nugraha, B., Sianturi, I., & Aini Rakhman, R. (2023). The Effect Of Supply Chain Management And Corporate Communication Skills On Production Performance At PT. Berlian Manyar Sejahtera. *International Journal of Science, Technology & Management*, *4*(6), 1477-1485. https://doi.org/10.46729/ijstm.v4i6.966.
[43]. Parulian Simanjuntak, G., & Sensi W, L. (2023). Evaluation Of The Implementation Of The Internal Audit Capability Model (IACM) Level 3 In The Supervision System Of The Inspectorate General Of The

Ministry Of Agriculture. *International Journal of Science, Technology & Management*, *4*(6), 1581-1602. https://doi.org/10.46729/ijstm.v4i6.1011

[44]. Hanif Triyana, M., & Indah Fianty, M. (2023). Optimizing Educational Institutions: Web-Based Document Management . ***International Journal of Science, Technology & Management***, *4*(6), 1653-1659. https://doi.org/10.46729/ijstm.v4i6.976

[45]. .Valdiya, KS. 1984. Aspects of Tectonics focus on south-central Asia, Tata Mc Graw – Hill, Publihing Company Limited, New Delhi.