

Indonesia telah berkomitmen pada agenda *Net Zero Emission* (NZE) 2060, yang mendorong pengurangan penggunaan batubara dalam bauran energi nasional. Di sisi lain, cadangan batubara Indonesia masih melimpah, sehingga diperlukan pemanfaatan alternatif yang bernilai tambah. Salah satu opsinya adalah pemanfaatan batubara sebagai sumber *Rare Earth Elements and Yttrium* (REY). Seiring meningkatnya permintaan global, dan keterbatasan deposit konvensional mendorong eksplorasi REY dari sumber non-konvensional seperti batubara dan abu pembakarannya, yang diketahui memiliki konsentrasi setara atau lebih tinggi.

Salah satu cekungan batubara yaitu Cekungan Pasir menjadi lokasi menarik untuk dikaji karena memiliki formasi pembawa batubara berumur Eosen dan rekam aktivitas vulkanik yang berpotensi memperkaya batubara dengan REY. Penelitian ini bertujuan untuk mengetahui karakteristik batubara, konsentrasi REY, moda keterdapatannya, serta proses pengayaan REY pada batubara Formasi Tanjung di Daerah Petangis, Cekungan Pasir, Kalimantan Timur. Penelitian dilakukan melalui observasi lapangan, pengambilan sampel dengan metode *ply-by-ply* sampling, dan analisis laboratorium yang meliputi petrografi sayatan tipis, petrologi organik, *X-Ray Diffraction* (XRD), proksimat dan ultimat, *Inductively Coupled Plasma-Mass Spectrometry-Atomic Emission Spectrometry* (ICP-MS/AES), serta *Electron Probe Microanalyzer* (EPMA).

Hasil penelitian menunjukkan bahwa litotipe batubara terdiri atas *dull non-banded*, *bright non-banded*, *slightly bright non-banded*, dan *dull banded*. Kelompok maseral *vitritinite* merupakan komponen utama penyusun batubara, dengan kelimpahan 57,25–81,72 vol.%, diikuti oleh *liptinite* dengan kelimpahan 0,87–21,67 vol.% dan *inertinite* sebesar 0,88–17,07 vol.%. Kandungan *mineral matter* berkisar 3,27–10,04 vol.% dengan nilai *ash yield* berkisar 14,43–67,67 (%adb). Rata-rata konsentrasi total REY di *Seam E, B, dan L* berturut-turut sebesar 84,29 ppm, 82,95 ppm, dan 83,35 ppm, lebih tinggi dibandingkan nilai rata-rata REY pada *world hard coal* (68,61 ppm). Moda keterdapatan terikat pada mineral autigenik pembawa REY (*REY-bearing minerals*) seperti kelompok mineral fosfat (apatit), silikat (kaolinit, *talca*), sulfida (pirit, sfalerit), *Ti-oxide* (rutil, ilmenit), *Fe-oxide* (*geothite*), *Al-oxide* (*corundum*), dan karbonat (kalsit, *smithsonite*).

Proses pengayaan REY diidentifikasi secara poligenetik, melibatkan tipe pengayaan *terrigenous*, *tuffaceous*, *infiltrational*, dan indikasi *hydrothermal*. Faktor yang berperan meliputi pelapukan dan pencucian batuan *basement* berupa mafik-intermediet, kehadiran lapisan *tonstein*, pengaruh air laut, dan adanya intrusi magmatik. Penelitian ini diharapkan menjadi dasar pemanfaatan alternatif batubara yang bernilai tambah sebagai sumber REY, serta mendukung *green energy*, *circular economy*, dan keberlanjutan.

Kata kunci : *Rare Earth Elements and Yttrium* (REY), pengayaan dan moda keterdapatan, batubara Formasi Tanjung, Cekungan Pasir

ABSTRACT

Indonesia has committed to the Net Zero Emission (NZE) 2060 agenda, which encourages the reduction of coal consumption within the national energy mix. However, Indonesia's abundant coal reserves encourage the need for alternative utilization. One such approach involves the utilization of coal as a source of rare earth elements and yttrium (REY). As global demand increases, and the limitations of conventional deposits encourage exploration of REY from unconventional sources such as coal and coal ash, which are known to have concentrations comparable to or higher than conventional ore deposits.

Pasir Basin represents a geologically promising coal basin due to its Eocene-aged coal-bearing formations and evidence of syn-depositional volcanic activity, which play a significant role in REY enrichment. This study aims to investigate the coal characteristics, REY concentrations, modes of occurrence, and enrichment processes in the Tanjung Formation coal within the Petangis area, Pasir Basin, East Kalimantan. Field investigations were conducted using a ply-by-ply sampling method, followed by laboratory analyses including thin-section petrography, organic petrology, X-ray Diffraction (XRD), proximate and ultimate analyses, Inductively Coupled Plasma–Mass Spectrometry/Atomic Emission Spectrometry (ICP-MS/AES), and Electron Probe Microanalysis (EPMA).

Results show that the coal lithotypes comprise dull non-banded, bright non-banded, slightly bright non-banded, and dull banded types. Vitrinite is the dominant maceral group (57.25–81.72 vol.%), followed by liptinite (0.87–21.67 vol.%) and inertinite (0.88–17.07 vol.%). Mineral matter ranges from 3.27 to 10.04 vol.%, with ash yield between 14.43% and 67.67% (adb). The average total REY concentrations in Seams E, B, and L are 84.29 ppm, 82.95 ppm, and 83.35 ppm, respectively, exceeding the global average for hard coal (68.61 ppm). REY are primarily associated with authigenic REY-bearing minerals including phosphate (apatite), silicate (kaolinite, talc), sulfide (pyrite, sphalerite), Ti-oxide (rutile, ilmenite), Fe-oxide (goethite), Al-oxide (corundum), and carbonate (calcite, smithsonite).

REY enrichment is interpreted as polygenetic processes, involving terrigenous, tuffaceous, infiltrational, and hydrothermal mechanisms. Influencing factors include weathering and leaching of mafic to intermediate basement rocks, the presence of volcanic ash (tonstein), marine influences, and magmatic intrusions. This study contributes scientific knowledge for the alternative utilization of coal as a REY resource, in support of green energy, circular economy, and sustainability.

Keywords: *Rare Earth Elements and Yttrium (REY), enrichment and mode of occurrence, Tanjung Formation, Pasir Basin.*