Geological-Structural Interpretation of the Croatian Parts of Dinarides Knin-Ravni Kotari and Eastern Part of the Adriatic Basin Based on 2-D Seismic Reprocessing, Geological Map and Wells Data*

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Abstract

Croatian Dinarides zone which consists of External Dinarides transition zone, (high karst zone). Central zone, Dinarides frontal thrust, SW marginal zone, slope zone of Dinarides Platform and Adriatic Basin is an extended zone of the Alps. Hydrocarbon shows were detected in some wells which were drilled in the Central zone (close to the town of Zadar). The areas of interest in this study are Knin-Ravni Kotari and eastern part of the Adriatic Basin. Knin high karst zone and Ravni Kotari with weathering zone reproduce very low signal to noise ratio on seismic lines. Seismic image of these seismic lines is not suitable for reliable seismic, neither for geological-structural interpretation. Satisfactory seismic image was obtained by applying certain seismic algorithms in these seismic lines. Geological structural interpretation was performed in particular in seismic lines reprocessing. By applying these seismic lines and combining them with geological maps and wells data we have made geological-structural profile of External Dinarides transition zone to eastern part of the Adriatic Basin. On this profile we have reconstructed better geological-structural relation of this area and also zones for potential hydrocarbon traps.

Introduction

The Dinarides are a 200-300 kilometer wide southwest vergent foreland fold and thrust belt extending in a northwest-southeast direction along the eastern side of the Adriatic Sea. Their northern end abuts against the Southern Alps, which have an east-west structural trend. Their southern end extends into Albania and Greece, connecting with the Hellinides.

The Dinarides have been dived into four major zones or terrains: the Internal Dinarides, the central Dinarides, the External Dinarides and the Budva Zone. (Figure 1).

The Internal Dinarides are characterized by the presence of weakly to strongly metamorphosed and deformed Paleozoic rocks, widespread Mesozoic ophiolites, and Tertiary intrusives and volcanics. This terrain, which comprises the hinterland of the thrust belt, marks the suture zone between the Adria-Apulia microplate and the continent fragments of Eastern Europe.

The Central and External Dinarides, the foreland zones of the belt, are composed of a thick section of Late Paleozoic and Mesozoic sedimentary rocks (Alpine sedimentary cycle) deposited on a basement of Paleozoic metasediments prior to thrusting. The section is dominated by shallow-water marine carbonates. The foreland zone of the Dinarides is separated into Central and External areas because of distinct differences in the complexity and age of deformation. The Dinarides are one of several Alpine orogenic belts in the Mediterranean area. The predominant transport direction from our interpretation is from NE to SW, toward the Adriatic coast. The thrust belt is southwest vergent having developed in Early Cretaceous to Miocene time during the closing of the Neotethys Ocean. In general, older rocks are progressively involved in the thrusting as one moves northeastward.

Structural Interpretation

For this purpose we constructed one balanced cross-section across Adriatic Sea wells, the Velebit Mountain till to the Bosnian border (Figure 2 and Figure 3).

The Velebit Mountain, where a complete sequence of Carboniferous through Jurassic rock crop out, represent a fault bend fold. All unit older than Jurassic form a hanging wall ramp which truncate at this trend. This fault was result of movement Una strike-slip fault, which is right lateral. Una strike-slip fault caused thin skin tectonic in area Ravni Kotari. Decollement are Mesozoic evaporates. The Triassic and Jurassic footwall sequence is interpreted to be autochthonous or peri-autochthonous in the Ravni Kotari and Adriatic coastal islands.

Seals

Several horizons of varying lithology have been identified as seals or potential seals in the Dinarides. The most important units are evaporates complex in the Permo-Triassic and Jurassic-Cretaceous sections. Potential seals are also noted in association with regional unconformities (Anisian – Ladinian; Ladinian - Carnian; Late Jurassic - Early Cretaceous), and associated with transgressive or drowning episodes within the Mesozoic carbonate platform Anisian – Ladinian volcaniclastic sequence; Liassic “ Lithiotis” depositional assemblage: Kimmeridgian Lemeš sequence.

Reservoirs

Two major lithofacies in the Dinarides have been noted that represent potential hydrocarbon reservoirs; Late Paleozoic to Early Triassic siliciclastic, and Permian to Late Jurassic dolomite. Reservoir quality of siliciclastic units is highly variable due to the nature of the matrix and cementing agents. The predictability of porosity systems of the carbonates is generally more complex than in siliciclastics. Primary depositional porosity is progressively lost during burial through mechanical process and chemical compaction of the sediment. Important porosity forming processes that operate in the burial realm are mainly of three types: 1) dolomitization, 2) dissolution, and 3) fracturing. Porosity formation in Dinarides area carbonates is the result of the interaction of all three variables.

Source Rocks

Three stratigraphic intervals contain source rocks that appear capable of generating hydrocarbons in great enough quantities to provide exploration opportunities. The intervals are the Triassic (Ladinian - Carnian), the Late Jurassic (Malm) Lemeš facies, and the Cretaceous Albian – Senonian.

Description of Seismic Data

On the Dinarides area, there is about 300 km generally poor quality of 2-D crook seismic lines. Data are divided geographically into three separate areas: the Plitvice lines, just a few kilometers southwest of Bihac; the Ravni Kotari lines from the Adriatic coast to the town of Knin; and five isolated Individual lines in the offshore that are scattered from Split in the South to the Island of Susak in the North. The data from Ravni Kotari have higher ratio signal to noise then other two areas. There are two very significant weaknesses in the data set. First is the low signal to noise ratio and second weakness could be addressed to the acquisition parameters. Data are maximum 48 fold and maximum offset is too short till 2200 m. Some seismic lines have been reprocessed in the Ravni Kotari area to improve signal to noise ratio. New technique was applied in order to remove noise and enhance signal from seismic data set (row shot gather, Figure 4).

We used K-L transform proceeds by forming a covariance matrix from the dot products of all the pairs of traces in the gather. Then it computes eigenvalues and eigenvectors for this matrix. One could then reconstruct the whole data set using all the eigenvectors scaled by their eigenvalues to return the original data field. This approach holds that all but the NEIGEN number strongest eigenvectors are dominated by noise (non-flat events). After that processing, we reduced flat events (Figure 5).

After that, we processed shot gather with designs a two-dimensional COHERENCE filter, to remove dipping coherent energy and noise, manifested as transverse dipping events from shot gathered seismic data (Figure 6). Additionally we applied refraction statics solutions from first

arrival times and processed CDP gathers with seismic program for surface-consistent statics solution. Finally, seismic data have been applied on the floating datum.

Conclusions

The most promising area for hydrocarbon discovery in the Dinarides are the “Central zone” of Ravni Kotari where characteristic sedimentary unit of the Alb-Cenomanian Sabkha sequence contains indication of oil in wells Ravni Kotari-1 and Nin-1. This unit was considered as potential source rock and seal interval for hydrocarbon migrated most likely from Triassic source rock of Muć type or Karnian euxinic shale of Vlasta-1 type. In the well, which was drilled near island Vis, certain quantity of oil and gas was discovered and is supposed to be regional oil bearing in the Karnian euxinic shale.

Interpretation of the seismic line Knin – Žirje that intersect a Zone of Proximal Thalus was very promising. This zone was also considered as unit of very good reservoir properties overlaying previously mentioned Triassic potential source interval. This unit was buried under the Tertiary clastic as good seal interval. This zone extends from Savudria in Istria to the Prevlaka in Dubrovnik offshore over 600 km long and represents a biggest exploration unit in Eastern Adriatic area. It should be emphasized that this zone was not tested with an exploratory well.

Final results of the described interpretation are recommendation of two prospects in the first phase of new exploration. One promise lead is Popovići with proposal well Popovići-1 situated near Benkovac town in Ravni Kotari province (see page 2.). The main target in this projected well is encountered in relative shallow depth of 2,500 m accommodated between frontal and back thrust of Upper Cretaceous Paleogene carbonate buried under Tertiary the Promina clastic formation. The second prospect is represented with carbonate platform’s margins buildups in Croatian Adriatic offshore.

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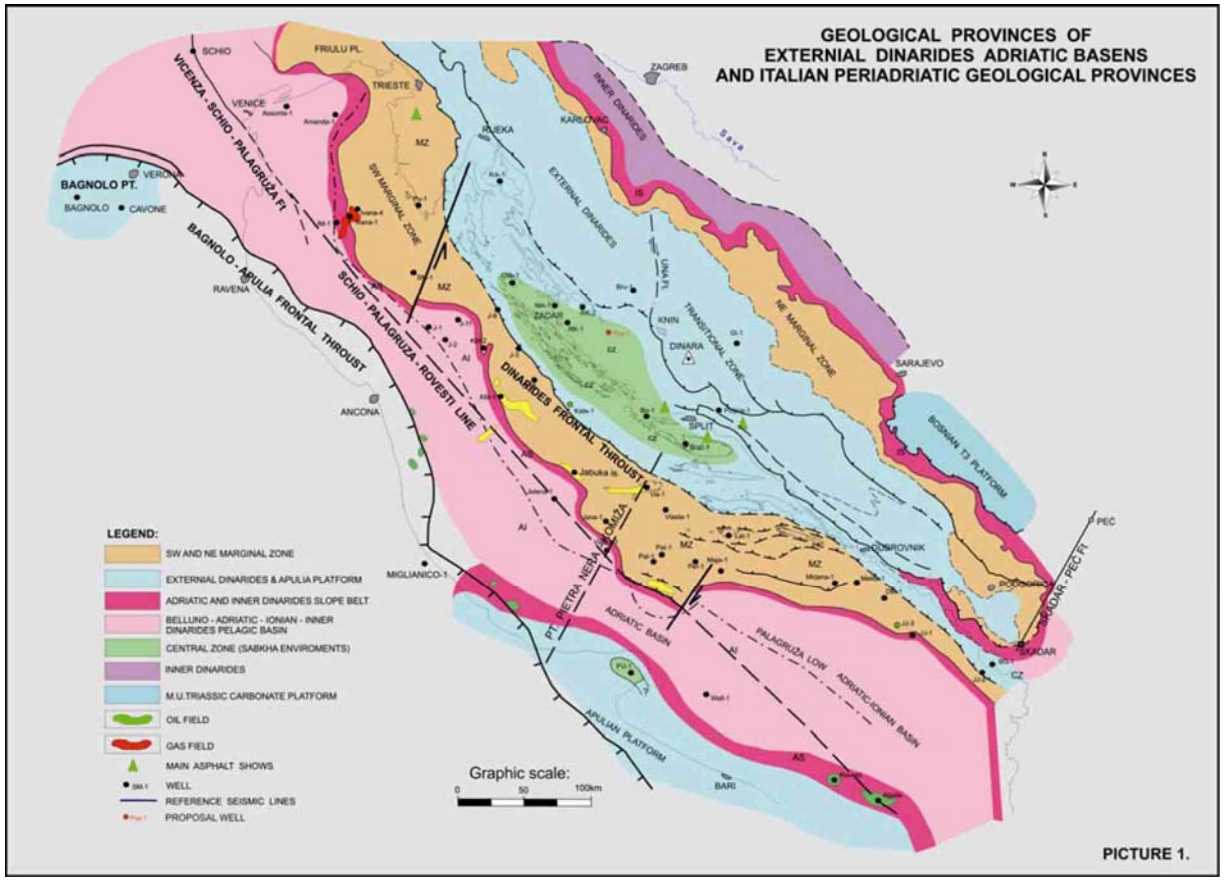


Figure 1. Geological Provinces of External Dinardies Adriatic Basins and Italian Periadriatic Geological Provinces.

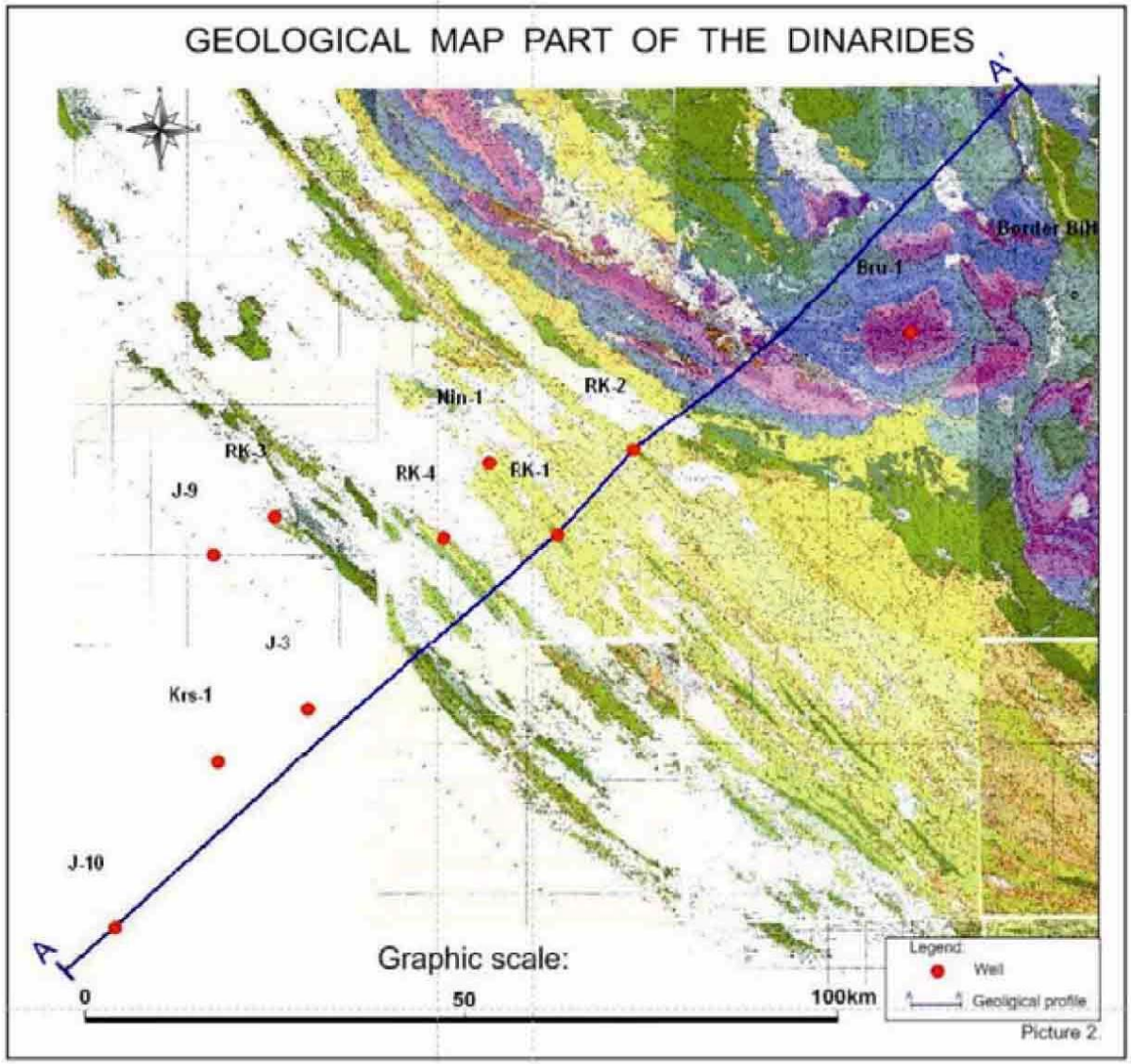


Figure 2. Geological Map part of the Dinarides.

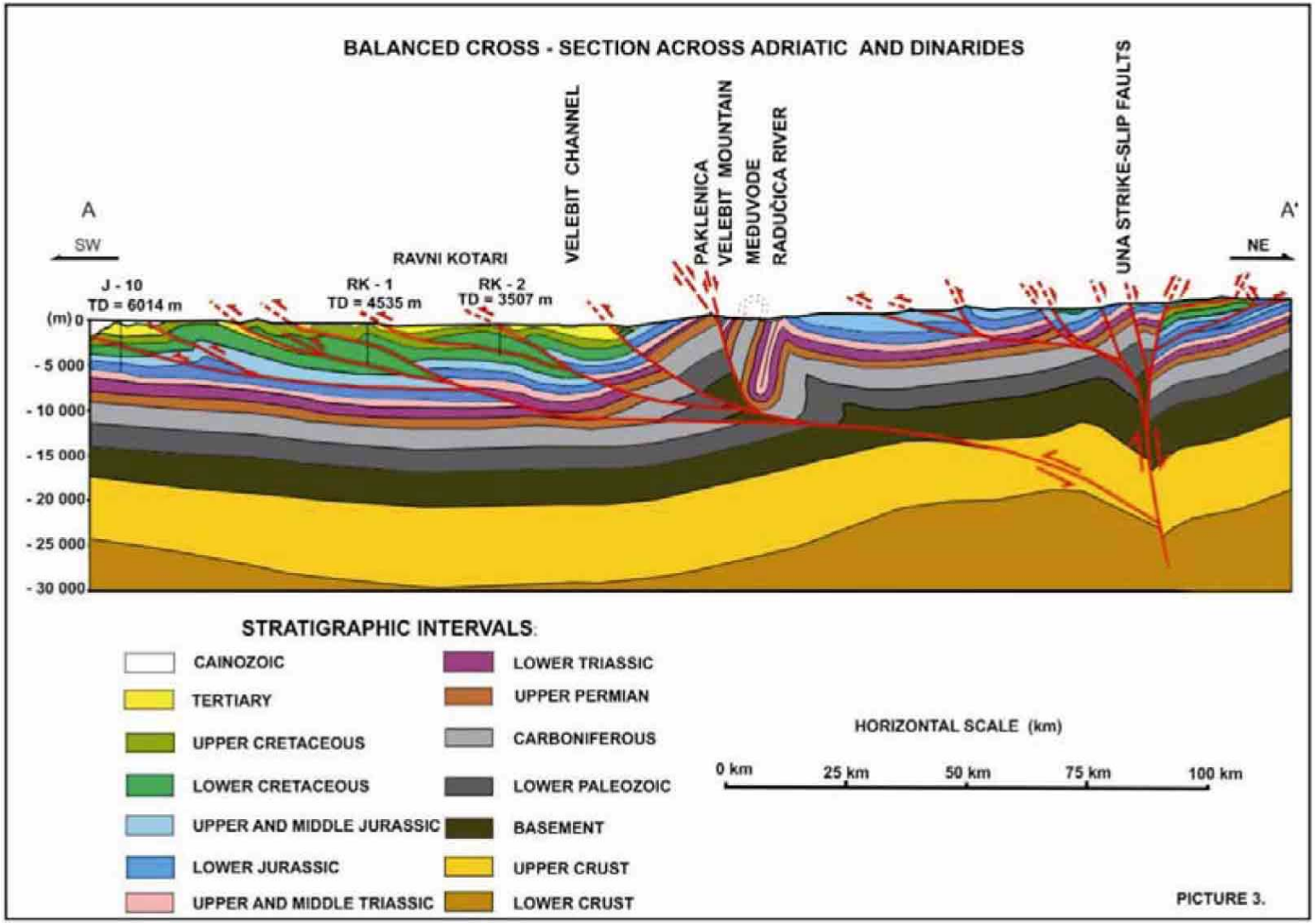


Figure 3. Balanced Cross-Sections across Adriatic and Dinarides.

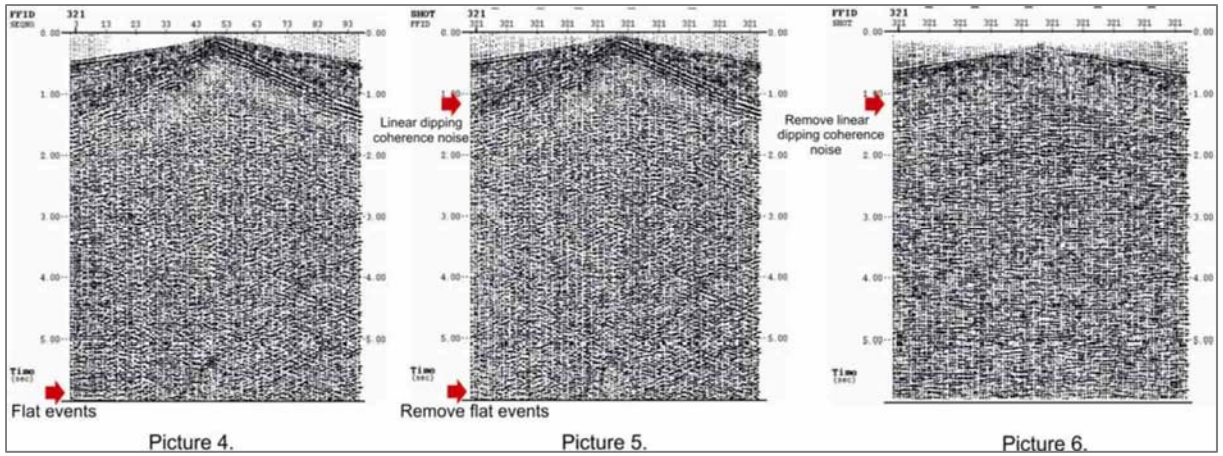


Figure 4. Shot Gather Number 321 from the KNIN-IV-89 Crook Seismic Line: Flat Events.

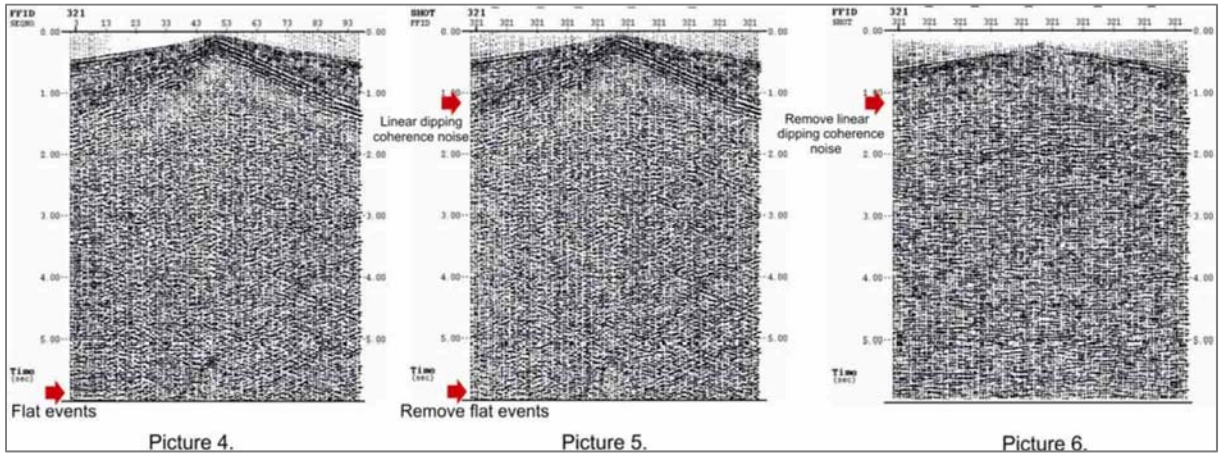
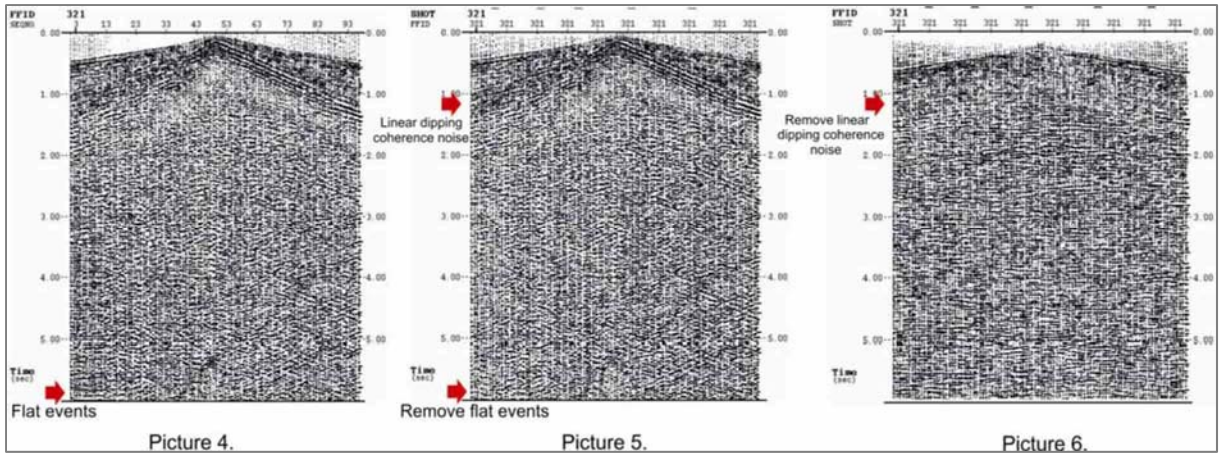


Figure 5. Shot Gather Number 321 from the KNIN-IV-89 Crook Seismic Line: Remove Flat Events.



Picture 4. Picture 5. Picture 6.

Figure 6. Shot Gather Number 321 from the KNIN-IV-89 Crook Seismic Line: Remove Linear Dipping Coherence Noise.