Application of Kirchhoff prestack time migration method of the 2D marine seismic data for mapping the subsurface structures in dip case Southern Aru, West Papua, Indonesia

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Abstract. The natural resources of oil and gas potential in the West Papua waters constitute a significant expansion of oil and gas investments in Indonesia's maritime specifically the eastern region. South Aru is located at the eastern edge of the basin trough Aru and includes one of the most potential oil and gas basins. Complex geological structures such as the case of large dip make seismic cross section results do not represent the subsurface structure of the earth nearing the actual subsurface geological conditions. The working principle of Kirchhoff prestack time migration is looking for reflector positions using delay time of wave energy reflection to get a better seismic section on the tilted reflector with less diffraction effect and have little effect arch (smiling effect) which generates seismic section that can represent the subsurface structure of the earth. Reflectivity cross section of generally more clearly observed after the migration process is carried out so that the resolution of cross section seismic better, which can be useful as the data is ready to be interpreted as the purposes of determination prospects of natural resources, especially regarding the hydrocarbon potential of the South Aru, West Papua waters.

1. Introduction

The natural resources of oil and gas potential in the West Papua waters constitute a significant expansion of oil and gas investments in Indonesia's maritime specifically the eastern region [1]. The Aru islands have administrative boundaries, namely the south of the Arafura sea, the territorial waters between Australia and the island of Papua in the Pacific Ocean. Aru is located at the eastern edge of the basin trough Aru and includes one of the most potential oil and gas basins [2]. There are several geophysical methods that can be used to find out how the condition of the subsurface structure, one of the methods used is the seismic reflection method.

The seismic reflection method is one a geophysical method that is used to observe the state of the subsurface structure (geological structure) with a target of considerable depth far enough by using the principle of propagation of seismic waves [3]. Recorded seismic waves carry a lot of information about the condition of the subsurface structure, measuring the elastic properties of the rock boundary, detecting variations in rock properties to the fluid information. Shown by wave travel time, wave amplitude and phase variations. This method is a method that gives a good overview of the structure of the subsurface layer with a better level of accuracy than other geophysical methods [4]. Seismic methods, especially seismic reflection method an important role in the exploration of hydrocarbons now. Seismic data processing is the most important step, where this stage is a very influential stage, where the process of
data that has been recorded at the data acquisition stage is processed into a seismic section, so that it can produce seismic sections that can represent the actual subsurface structure of the subsurface geology [5]. Returns diffraction energy to its scattering point to eliminate undesirable deformation (distortion) from seismic recordings and maps seismic events to the actual position where this process is known as seismic migration [6].

The theory used in migration is a zero-offset recording scheme by placing the source and receiver in the same location along the survey line without distance [7]. The fact is to get such data is not easy. Kirchhoff prestack time migration shows the non-zero-offset concept. In the migration process with kirchhoff migration technique produces a subsurface cross section of a more continuous reflector, and corrects the diffraction effect. The speeds used in the kirchhoff prestack time migration process is \( v_{rms} \) [8].

Based on consideration of the case of research data, namely the complex geological structure where there is a dip in the data with a large angle so that migration needs to be done in the time domain. To migrate to this type we choose an appropriate algorithm. Migration algorithm or method according to the case of research data and can be explained by the kinematic is kirchhoff migration. With consideration and the case of the data already described above, in this research the application of kirchhoff prestack time migration method of the 2D marine seismic data for mapping the subsurface structure in dip’s case Southern Aru, West Papua, Indonesia.

2. Methods
Data processing uses ProMAX 2D software to produce an optimal cross section that is a better seismic cross section on the reflector with a smaller diffraction effect and the outputs produce a slight smile effect. The method that will be processed in this research is Kirchhoff prestack time migration. The acquisition data is processed to eliminate the recorded noise. The research data is that there is a large angle dip effect so that the Kirchhoff prestack time migration method is applied, with the results of a migrated seismic cross section that produces optimal subsurface seismic cross-sectional imaging.

The location of the research area borders the Northern Aru archipelago with an area of 39.340 \( km^2 \) or a length of 215 \( km \) to the northwest - southeast and a width of 180 \( km \) to the northeast – southwest. The coordinates of the survey locations in Table 1. Map of the location of the seismic research survey of the Southern Aru, West Papua, Indonesia in Figure 1.

| Longitude     | Latitude          | X (UTM 84) | Y (UTM 84) |
|---------------|-------------------|------------|------------|
| 133° 36’ 11.6712” | -5° 47’ 9.9492”  | 345,347    | 9,360,251  |
| 135° 28’ 19.8588” | -6° 20’ 56.0292” | 552,223    | 9,298,204  |
| 136° 1’ 39.1548” | -4° 49’ 16.2516” | 613,944    | 9,467,016  |
| 134° 11’ 58.6464” | -4° 14’ 40.2396” | 411,178    | 9,530,800  |

Table 1. Coordinates of the survey location
Research starts from March to June 2018 at the center for research and development of marine geology.

3. Results and Discussion

The research results obtained from the migrated seismic cross section by proMAX 2D as shown in Figure 2 starting by mapping further reflectivity to the seismic cross section produced based on the reflectivity of seismic facies including continuity, pattern/configuration, and reflection amplitude. Then the extent to which changes in reflectivity produced as a result of the migration process. Migration aims to create a seismic section is similar to the actual geological conditions based on the reflectivity of the earth's layers. Signal reflections are recorded by hydrophones sea surface is influenced by the geometry of subsurface area of the survey sites.

In this research seismic recordings were processed on line 12 from Southern Aru, West Papua waters because the line had a dip effect with a large angle so it needed a method according to the case in this research, the author tried to apply Kirchhoff prestack time migration as test data to determine most appropriate. Prestack time migration using the Kirchhoff migration method is selected because for the ability of this method to migrate under non-zero-offset conditions. Another advantage to using this method is because this method is able to overcome an imprecise seismic data trace distance. However, Kirchhoff's migration method has a weakness, namely the inability to accurately describe speed when there are complex structures caused by approximations that are often used in presenting and calculating green functions, travel time and amplitude [9]. The basic principle of the Kirchhoff migration method is to find the reflector position using the reflection time delay energy recorded at the time of data acquisition [7].

Figure 1. Map location of the seismic survey research Southern Aru, West Papua, Indonesia. Aru has an administrative boundary, namely the southern with Arafura Sea, which is territorial waters between Australia and Papua Island in the Pacific Ocean.
Figure 2. Analysis of 2D seismic cross section of Kirchhoff poststack time migration results.

The seismic cross section of the Kirchhoff poststack time migration results describe subsurface conditions that still not well. This condition is caused by the dip effect which divides the subsurface into two different geological conditions, where the right part of the seismic section has different seismic velocities. It is likely that the reality occurs in the field is in the form of different density coated sediments.

From the pattern can be seen reflection events with continuity and amplitude that represent a reflector field. The intended reflector is the signal source mashing the boundary between different elastic medium densities and reflected upwards based on Snell's legal principle. The intended reflector is the source signal pounding the boundary plane between the elastic medium which is different in density, then reflected upwards based on Snell's law principle. Reflectors are characterized by relatively large amplitude compared to the amplitude of other signal recording or regarded as noise. The amplitude of vibration will shrink because some of the wave energy is absorbed by the rock layer to be heat energy. This is caused by friction between the bedrock particles in the rock. Then the reflection effect will result in the vibration amplitude of the deeper reflections being weaker, because some of the energy has been reflected by the plane of reflection in the shallow part.

The migration process is carried out to correct the reflection in the form of a reflector position inclined reflector or a field non-horizontal field. The result migration of reflectivity of the subsurface layer is more clearly observed. The cross section in Figure 2 describes the visible reflector is not clear because the reflector is not the actual reflector, it is thought that dispersive noise is recorded in the research data acquisition process in the seismic survey of the South Aru, West Papua waters. After Kirchhoff poststack time migration was carried out, the subsurface structure with the appearance of the reflector had not been too clearly visible and the dip angle still appeared large and sharp in the research data. Then it is necessary to do prestack time migration using the Kirchhoff migration method to reduce the effect of dip which looks large and sharp in the research data.
Figure 3. Analysis of 2D seismic cross section of Kirchhoff prestack time migration results.

Kirchhoff prestack time migration seismic cross section produces a cross section that describes the actual seismic cross section conditions similar to Kirchhoff poststack time migration, the difference is that Kirchhoff prestack time migration produces a better resolution, the reflector appearance looks more continuous, the pattern is continuous and regular and the dip effect is noticeably reduced in research data. Kirchhoff prestack time migration effectively reposition the reflector. The output of migration results is the time migrated section.

The reflector continuity results from Kirchhoff prestack time migration method effectively eliminates diffraction patterns so that the structure depicted by the seismic cross section is clearly visible on the reflector depiction. Seen in Figure 3 more clearly and more focused than the results of the Kirchhoff poststack time migration.

Kirchhoff prestack time migration aims to make seismic cross sections similar to the actual geological conditions based on the reflectivity of the earth layers and reduce dip effects in research data caused by changes in rock density contrast in the boundary plane between layers. In general Kirchhoff prestack time migration reflector changes to be steeper, indicated in the cross section of the migration which can be a significant change in dip angle. The amplitudes position of the reflection in the Kirchhoff prestack time migration brings the slope information of a reflector field. The reflector tilt information is tan θ is one that influences the results of migration which is produced in addition to velocity analysis. This dip's effect affects large vertical shifts and large horizontal shifts [10]. This speed difference is not count and facilitated by normal move out (NMO) which uses a zero-offset assumption. Kirchhoff poststack time migration uses the zero-offset assumption while Kirchhoff prestack time migration uses the non-zero-offset assumption.

Migration generally uses CDP gather which has been NMO corrected so that its gather becomes flat. Comparison of the results of Kirchhoff prestack time migration and Kirchhoff poststack time migration is the result of Kirchhoff prestack time migration provides better imaging quality compared to Kirchhoff poststack time migration results. Then it can be seen that the results of kirchhoff prestack time migration Figure 3 are able to reposition the reflector position clearly and continuously and improve the quality of imaging. The overall reflector pattern and the continuity produced by the migrated seismic cross section can be illustrated regularly, and have good resolution. Seismic data in this research can be used as seismic cross sections that are ready to be interpreted later.
4. Conclusions
Based on the research that has been done, by applying of Kirchhoff prestack time migration method of the 2D marine seismic data for mapping the subsurface structure in dip's case Southern Aru, West Papua using ProMAX 2D Linux software program, it can be concluded that from the results application of Kirchhoff prestack time migration method of the 2D marine seismic data for mapping the subsurface structures in dip case Southern Aru, West Papua, Indonesia obtained the conclusion that an analysis in the form of subsurface structural reflectivity, when the migration cross section is not optimal, Kirchhoff prestack time migration is applied that can resulting in a better cross section on the reflector with a smaller diffraction effect and the output results have a slight smiling effect. The result from Kirchhoff poststack time migration, where is the cross-section condition gives dip a big smile effect, especially on the right side of the cross section that is after dip, due to improper velocity. while Kirchhoff prestack time migration results effectively eliminate diffraction patterns so that the structure depicted by the seismic cross section is clearly visible in the reflector and optimal representation, compared to Kirchhoff poststack time migration results. Seismic data in this research can be used as seismic cross sections that are ready to be interpreted later.

5. References
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