With the extensive development of electronics and information systems, there has been an expansion of the use of remote sensing techniques; especially satellite imagery which has emerged as an effective means for studying the environment, the features of the earth’s surface and its natural resources such as water, soil, rocks, and vegetation cover, at local, regional, and international scales, and on a multitemporal basis.

His Royal Highness, Prince Sultan bin Abdulaziz, Crown Prince, Deputy Prime Ministers, Minister of Defense and Aviation and Inspector General financially supported the project to develop the *Space Image Atlas of the Kingdom of Saudi Arabia* through the Sultan Bin Abdulaziz Al Saud Foundation. The Prince Sultan Research Center for Environment, Water, and Desert at King Saud University initiated the project and conducted it in cooperation with a group of distinguished specialists from the following institutions: King Saud University, Space Research Institute at King Abdulaziz City for Science and Technology, General Commission for Surveys, King Fahd University for Petroleum and Minerals, and Geospace-Austria.

The *Space Image Atlas of the Kingdom of Saudi Arabia* employs remote sensing techniques and digital satellite image processing to obtain a comprehensive view of all features of the Kingdom’s surface from space. It exists both as a printed book and in digital format.

The *Atlas* is divided into a number of chapters, beginning with a general introduction to Remote Sensing techniques, Digital Satellite Image Processing, and Geographic Information Systems. The first chapter then takes up the Geography of Saudi Arabia by displaying summarized information on most of its geographic features, with the overlay of a map of each of these elements over the mosaic of satellite images of the entire Kingdom. The second chapter displays the major cities of the Kingdom through high-resolution satellite images along with summarized information on these cities. The third chapter contains satellite images of selected sites displayed at various scales, taken by different satellites, and showing the most important morphological and specific characteristics of the Kingdom, as well as its major environmental phenomena, geographic features, and natural resources. The images are accompanied by a summary on each subject. The fourth chapter presents a series of sheets of satellite images taken by Landsat-5 satellite. The images were geometrically corrected, color-enhanced, and processed in a unified manner at a scale of 1:500,000. As a group they cover all regions of the Kingdom, and each sheet includes the names of the most important sites.

The *Atlas* comprises an important reference that enables researchers and specialists to better understand the Kingdom’s history and archaeology, its geographic features, modes of land use, urban expansion, and distribution and management of natural resources. It offers major examples of the Earth’s phenomena, and it has been a starting point for the initiation of specialized projects. The *Atlas* has also helped in obtaining information on changing environmental phenomena in the Kingdom. In this way, the *Atlas* can contribute to protecting the environment from pollution, combating desertification, limiting sand dune encroachment, and providing solutions for numerous problems associated with natural hazards.

What follows are sample pages from the *Atlas* that represent the content of the various chapters.
Remote Sensing Technology

Remote sensing technologies are effective operational tools in studying and exploring the Earth's geology and its surface resources, atmosphere, and biosphere. Through these techniques, successive high-quality images of extraterrestrial areas can be collected using appropriate sensors mounted on aircraft or satellite platforms. These sensors differ greatly in design, construction, and operation. Some airplanes and satellites are equipped with optical sensors, which receive reflected or emitted electromagnetic energy within certain wave lengths from Earth's surface and transmit it to ground receiving stations where it is digitally processed and converted into photographic or image. Other airplanes and satellites carry radar systems, which generate their own energy waves and send them to the ground. The intensity and range of the reflected waves received back and these images are consequently produced. Thanks to the rapid advancements in space technology, remote sensing techniques began to flourish particularly after the launch of the Landsat-1 satellite (ERTS1) in 1972. Since then many satellites, space labs and multipurpose space stations, including the Space Shuttle programmes have been launched. This project has been accompanied by a great improvement in sensors, spatial, radiometric, spectral and temporal resolutions and in the techniques of digital image processing. Satellites fall into two main types: The first comprises low orbit, non-synchronous earth observation satellites. Each of these satellites orbits Earth at an altitude of a few hundred kilometres and at a given angle of inclination. Prominent satellites of this type are the Landsat-1 series, NOAA, ERS-1, QuikBird, the Spot-5 series, the Indian IRS satellites, and the Japanese and European satellites. The ground resolutions of the sensors onboard these satellites vary greatly. The QuickBird sensor, for instance, can resolve an object larger than 0.4m. The equivalent figure for the ERS-1 sensor is about 10m while the SPOT improved push-broom sensor can resolve down to 3 m on the ground. The Landsat-7 Enhanced Thematic Mapper (ETM) can resolve objects greater than 25 m, and the Landsat 8 and 5 Thematic Mapper (TM) sensors have 30 m spatial resolution, while the ground resolution of the AVHRR sensor on board NOAA satellites is 1 km. The second type of satellite includes geostationary orbit, earth-synchronous meteorological satellites, which orbit Earth at an altitude of 36,000 km above the equator. The best examples of this type are the European Meteosat and the American GOES satellites. Remote sensing techniques have many applications including geological and geomorphological surveys, land use and land cover mapping, urban planning, satellite meteorology, rocket monitoring, and change detection. To illustrate, many sensor observations of the GoES satellite can be obtained in one hour.
As the land of divine revelation and the country responsible for the custody of the two Holy Sanctuaries of Makah and Al-Madinah, and the other sites of the rites of pilgrimage, Saudi Arabia enjoys a distinctive position. Its role in the Muslim world is enhanced by its system of governance based on the foundations of Islam, its active membership in Islamic organizations, such as the Muslim World League, and its support of Islamic causes. Its location at the center of the Muslim world (Fig. 1) has facilitated the travel of pilgrims for Hajj and umrah as well as trade with other Islamic countries.

The Kingdom has made prominent efforts in spreading Islam and building mosques worldwide, and in supporting charitable projects such as schools and orphanages. It has worked hard to provide aid to Muslim people affected by natural disasters, to help them resolve their social and economic problems, and to support them in times of need.

The Kingdom’s Status in The Islamic World

Mکانة المملكة في العالم الإسلامي
General Geographic Overview of The Kingdom

Saudi Arabia occupies some 2.1 million sq km, covering most of the Arabian Peninsula (Fig. 1), and in 2005 its population numbered about 22.7 million people, of whom 16.5 million were Saudi citizens. To the east, the Kingdom is bordered by Kuwait, Bahrain, Qatar, and the United Arab Emirates, and Oman on the Arabian Gulf, while to the west it is bounded by the Red Sea and the Gulf of Aqaba. To the north it borders Jordan and Iraq, and on the south, Oman and Yemen. The Kingdom is governed on the basis of the Islamic Shari'ah, which is the country’s legal system and constitution. Saudi Arabia has devoted special care to the two Holy Sanctuaries of Makkah and Al-Madinah, this responsibility has involved projects to develop the holy sites, and to provide efficient transportation networks for the pilgrims who come by land, air, and sea to perform the Hajj and Umrah. The Kingdom has deep historical and cultural roots, and a rich cultural and archaeological heritage. The country is divided into 13 administrative regions, each consisting of a number of districts, while the main city in each of these regions serves as its administrative center. Geographically, the Kingdom is made up of the Arabian Shield in the west and the Arabian Shelf to the east. Its surface features include shorelines and coastal plains, mountain ranges, plateaus, escarpments, gravel plains, wadis, sand dunes, salt flats, depressions, and oases flows. The Kingdom’s climate is predominantly continental, and it is an extension of the eastern Mediterranean climate, except for the southwestern parts, which are subject to humid tropical climatic influences, and As-Rub’ al-Khali, which has a dry tropical climate. The climate is characterized by hot, dry summers, except in the southwestern highlands, and by cool winters with limited rainfall. Atmospheric humidity is concentrated mainly in the coastal regions and low in the interior. The Kingdom’s water resources include surface waters and groundwater, desalinated seawater, and treated effluent. Its soils range from sandy to alluvial, limy, and saline; arable soils comprise about 5% of the country. A diverse natural plant cover includes woodlands in the southwest, while mangroves make up some 5% of the country. The Kingdom’s other natural resources include its mineral wealth and enormous reserves of oil.
Historical Routes of Pilgrimage

The historical pilgrimage routes leading to Makki al-Mukarramah and Al-Madinah al-Munawwarah include the following (Fig. 1):

1. The Khaq-Makki Route, known as ‘Arbah-Zubaydah’. 2. The Bawadi-Makki Route, joined by the Babara Route by way of Al-Yamanah. 3. The Egyptian Pilgrimage Route, which served the pilgrims from Morocco, Adriatic, and Adana through Egypt. 4. The Syrian Pilgrimage Route, which began in Damascus and ran through the Tabuk and then to Al-Madinah and Makki. 5. The Yemeni Pilgrimage Route to Makki, which ended in Damascus and ran through the Tabuk and then to Al-Madinah and Makki. 6. The two Omani Pilgrimage Routes: the first of these ran from Oman through Yathrib and Al-Yamanah to Makki; while the second passed from Oman through southern Arabia, from where pilgrims continued their journey by one of the Yemeni Pilgrimage Routes. In addition to these land routes, some pilgrims arrived by sea to one of the Red Sea ports and then traveled overland to Makki al-Mukarramah and Al-Madinah al-Munawwarah.

From the time of the founding, the Kingdom has taken care to develop road networks of the highest standard leading to Makki al-Mukarramah and Al-Madinah al-Munawwarah, and likewise to develop the sea and air transportation networks, facilitating access to these two cities for the pilgrims performing Hajj and ‘Umrah, and visiting the Prophet’s Mosque: Makki and the sacred site of ‘Arafat, Mina, and Muzdalifah. Mecca has seen a number of expansion and development projects related to the Prophet’s Mosque: Makki and the sacred site of ‘Arafat, Mina, and Muzdalifah, as has Al-Madinah al-Munawwarah. Among the most important of these projects was the great expansion of the Two Holy Mosques undertaken during the reign of King Fahd ibn Abdallah, the Custodian of the Two Holy Mosques. As a result of this expansion, the Holy Mosque in Makki now accommodates more than a million worshipers, while the Prophet’s Mosque in Al-Madinah al-Munawwarah accommodates around 500,000 worshipers.

A modern network of roads and infrastructure has been developed in the sacred sites of ‘Arafat, Mina, and Muzdalifah.
During Pliocene times, the Arabian Peninsula was part of the ancient continent known as Gondwana, the northern part of which was covered by the Tethys Sea. In the late Mesozoic Era and the beginning of the Cenozoic Era, this continent was subjected to tectonic activity, leading to upwarping and faulting of the western part. This resulted in a rift, into which flowed water from the Tethys Sea to form the Red Sea. The land of the Arabian Peninsula was then tilted downward to the northeast, increasing the expanse of the Red Sea. Strong lateral folding pressures in the eastern part of the Peninsula led to worm-like movements of its strata to form the basin of the Arabian Gulf, which was later submerged in the waters of the Indian Ocean. The Kingdom is divided geologically into the Arabian Shield in the west and the Arabian Shelf in the east. 

The Arabian Shield is composed mainly of igneous rocks, such as granite, diorite, and gabbro, and metamorphic rocks, such as gneiss, marble, and schist, with a few sedimentary rocks, such as limestone and sandstone. All of these rocks predate the Palaeozoic Era. During the Mesozoic and Cenozoic Eras, three rocks, especially the sedimentary rocks, were subjected to additional folding, uplifting, and erosion, while lava flows from volcanic eruptions produced basaltic lavas. The western part of the Arabian Shield is characterized by highlands such as the Mahyan Mountains in the north, the Hijaz Mountains in the center, the Aseer Highlands in the south, and in the western part of the Najd Plateau, the Ajan and Salem Mountains. The rocks of the Arabian Shield are rich in metallic minerals such as gold, silver, copper, iron, and iron. The Arabian Shelf is composed of sedimentary rocks formed gradually from the Palaeozoic through the Cenozoic Eras, such as carbonates, clays, sands, limestones, and salt deposits. These rocks form horizontal strata that were deposited, both conformably and unconformably, over the basement rocks of the Arabian Shield, in continental, deltaic, marine, and glacial environments. The strata of the Arabian Shelf are tilted with a slight angle dipping to the northeast, and they crop out in the form of parallel belts from the oldest to the most recent in the east. The Arabian Shelf is characterized by plateaus such as those of Najd and Sumr, basins such as that of Aseer, a fan-like, Ad-Dhubab, and Al-Jawf, and major wadis such as Wadi al-Rum, Wadi al-Sirhan, and Wadi al-Dummar. The rocks of the Arabian Shelf contain minerals such as bauxite, phosphate, anhydrite, and silica. These rocks also contain oil reserves, especially in eastern part of the Kingdom.
Saudi Arabia’s landforms are classified into several broad geomorphic units (Fig. 1). (1) Shores and Coastal Plains which are distributed along the Red Sea and Arabian Gulf. (2) Mountain Highlands including the mountains of Maniyah, the Hijaz and Aseer in the Sawmaa Range. (3) Plateaus such as Central Najd and the Hejira, Al-Sirman, and Shadhan plateau, and several other interior plateaus. (4) Escarpments and cliffs, such as Jabal Tuwayq, and Al-Urmaid Escarpments. (5) Gravel plains, which occur at mountain plateaus, plateaux, escarpments and cliffs, and some wadi channels and oases. (6) Wadis and Drainage Basins include wadis that flow from the Sawmaa Highlands to the Red Sea, such as Wadi Yahi, Wadi Baysh, and Wadi al-Lith, and others that end in inland basins or plains, such as Wadi al-Dawasir, Wadi Bihah, and Wadi ar-Ruma. This unit also includes internal draining wads in the interior of the Kingdom, such as Wadi Hanifa. The flow of some of these wads forms alluvial fans, such as the Shibamah fans at the termination of Wadi al-Batin. (7) Sand Dunes: more than one third of Saudi Arabia is covered with sand seas of the Al-Sa‘ Kha‘, Al-Nafud, Al-Dhil, and Al-‘Ula. Sand dunes are also found in Nafud al-‘Ulya and Nafud al-Dhil, some wads in the interior, and on the Arabian Gulf coast. (8) Salt flats and salt pans include coastal salt flats, found along the Red Sea and Arabian Gulf, and inland salt flats, which form in depressions among highlands or sand dunes, as in the regions of Al-Qasar and Wilil. (9) Depression basins in which rainwater collects and natural vegetation flourishes seasonally, such as Wadi al-Haymah and Wadi al-‘Asha‘. (10) Lakes: black brackish lagoons, such as Harat al-Harrah, Harat Buwaym, and Harat al-Bagham.
In winter, Saudi Arabia is generally dominated by high-pressure systems. Among the most important of these are the subtropical high-pressure system and the Azores high-pressure system, both of which are accompanied by strong winds and sometimes very cold winds, especially in the north of the Kingdom. On some winter days, however, Mediterranean dynamic low-pressure systems cross the country, generating atmospheric instability and rainstorms.

In summer, some parts of the country are affected by an extension of the Indian monsoon low-pressure system. This system is accompanied by southwesterly winds from Africa, which affect the southern and southwestern parts of the country, bringing rain and thunderstorms to the mountains heights. Oscillating high- and low-pressure systems dominate the Kingdom's weather in fall and spring.

\[ \text{Wind Direction and Speed} \]

\[ \text{Map of Saudi Arabia showing atmospheric patterns and wind direction.} \]

\[ \text{Figure 1: Wind rose shows relative occurrence of both directions and speed of wind in some cities of the Kingdom superimposed onto a raster of GTOPO30 imagery.} \]
The Kingdom is characterized by a diverse plant cover, that in some ecosystems is relatively dense. Approximately 2350 terrestrial plant species are distributed among a variety of biotopes, from mountains to plains, sandy plains, and salt flats. Distinctive plant communities characterize each of these biotopes. The area of the Kingdom’s rangelands has been calculated at 171 million ha, some 76% of the country’s total area. These rangelands include most of the plant communities illustrated in the satellite image (Fig. 1), the most important of which are communities of Capparis comosa, Xanthium spinosum, and Aerva species. A mosaic desertic plant cover consisting mainly of perennial herbs and grasses and spiny shrubs characterize these rangelands, annuals grow and flower after rains. Saudi Arabia’s woodlands cover approximately 2.7 million ha, some 1.2% of the Kingdom’s total area. Woodlands predominate on various levels in the heights of the Sawai Mountain Range, at altitudes above 1200 m on mountains such as Jabal Fuja’a, Jabal Radwa, Jabal al-Wad, and Jabal al-Lawwah. This range has a height of over 3000 m at its highest crest, Jabal ar-Rahid in the Asir Region. The woodlands in the southwestern part of the Kingdom constitute its main forest resource because of their diversity and density, as well as their role in reducing the severity of soil erosion caused by rains and floods, and enhancing the process of groundwater storage. Among the most important native trees in the Kingdom’s woodlands are the junipers, stands of which appear dark green in the satellite image (Fig. 1), where they occupy the mountainous summits. Rawdat Khair and Rawdat al-‘Alma’ are examples of vegetation growing in depressions in which rainwater gathers. Mangrove forests occur in coastal environments and islands in the Red Sea and Arabian Gulf.
The extraction, refinement, and export of petroleum play an important role in the Kingdom’s national economy, as it is the chief source of the country’s income. Petroleum was first discovered in the year 1938 in the Najd Province. Since then, the number of oil and gas fields in the Kingdom has multiplied, and others have been discovered in the Red Sea and the Arabian Gulf, in Saudi Arabia. From which very light Arabian crude oil is produced, and in the Shaybah field in the Empty Quarter (Fig. 1). A network of pipelines links these fields to refineries and terminals on the shores of the Arabian Gulf and the Red Sea. At the end of 2003, the Kingdom’s crude oil reserves stood at 253.4 billion barrels, while its reserves of natural gas amounted to some 234.5 trillion cubic feet. The Kingdom’s oil reserves constitute some 25% of the world’s reserves. In 2003, the average crude oil production rate was 8.1 million barrels per day, while the average production rate for natural gas was about 6.52 billion cubic feet per day. The Kingdom occupies a significant position in OPEC, as it owns more than 30% of OPEC’s organization’s shares.

Mineral resources also contribute substantially to the Kingdom’s economy, owing to the great diversity and high quality of the mineral deposits that have been verified by geological surveys. These minerals include phosphates, manganese, zinc, iron ore, copper, and gold, most of which occur in the Arabian Shield. Saudi Arabian Companies have been established and charged with the responsibilities of mineral exploration and the exploitation and development of mines, such as the Nakheel mill, Al-Sharab, and the Hijri and Sikkabzah mines.

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النفط والغاز والمعادن

يذكر استخراج النفط والغاز والمعادن من أهم مشاهير الاقتصاد الوطني للمملكة في بعض النواحي. وقد أدى استخراج النفط إلى نوعية مهملية من خلاله إلى اقتصاد المملكة حيث الديناميكية يشبه المعاملة في 나라 مصرفية. وحجز استخراج النفط وإقامة الصناعات الصناعية من حيث الاستفادة من موارد البترول والغاز. بناءً على ذلك، فإن النفط تميز الأراضي السعودية بوضع البترول، ويُعتبر الاحتياطيات البترولية السعودية من أكبر الاحتياطيات في العالم، حيث كشفت الدراسات الأثرية أن الاحتياطيات البترولية في السعودية تقدّم 210 مليار برميل، يمتلكها السعودية من حيث الاحتياطيات البترولية. إن الزراعة، الصناعة، والهندسة، والطاقة، والغاز، والمعادن، تقوم بتوفير الدخل والدخل في المملكة.

مصدر: مركز البترول السعودي.
Makkah al-Mukarramah

Makkah al-Mukarramah is situated in the west of the Kingdom at the edge of the Hijaz foothills that run parallel to the Red Sea (Fig. 1), at an elevation of about 800 m above sea level. The city is surrounded by mountains encircling Wadi Fathmah, and this topography has shaped in pattern of urban development. Makkah al-Mukarramah is the third largest city in the Kingdom, with a population that reached 1,294,818 in 2015. This sacred city, which grew up on an ancient trade route between Syria and Yemen, has the most lofty religious status in Muslims' hearts. Here revelation descanted on the Prophet Muhammad ibn Abdullah, upon him be peace and the blessing of Allah, and from it Islam spread: in it is the Holy Mosque (the Haram), in the center of which is the Ka’bah toward which Muslims throughout the world face in prayer, and in which the pilgrims standing for hajj and ‘umrah (Fig. 2). Makkah’s network of new roads, tunnels, and flyovers link the Holy Mosque to the sacred sites to facilitate the pilgrims’ journeys. It contains a number of historic centers and educational institutions.

Tightening Makkah al-Mukarramah, a major center and a holy site to Muslims, is a matter of great importance for the Kingdom of Saudi Arabia as a whole. Located in the center of the country, it is a sacred place for Muslims and serves as a pilgrimage destination. The city is known for its historic sites, including the Holy Mosque (Haram), the Ka'bah, and other religious landmarks. Makkah al-Mukarramah is not only a religious center but also a major tourist attraction, drawing millions of visitors every year. The city is home to several universities and institutions of higher education, as well as numerous cultural and historical sites.

Figure 1: Panorama of Makkah al-Mukarramah and other holy sites in Mecca, Madinah, and Yathrib.

Figure 2: Ka’bah, the holy cube, surrounded by the 12th-century third wall built by Sultan Al-Nasir Muhammad ibn Qalawun. It is one of the holiest sites in the Islamic world.

Figure 3: Pilgrims performing the Eid al-Adha at the Great Mosque of Makkah.

Figure 4: Plan of Archeological area of Makkah road 204 shown in the middle.
The city of Ar-Riyadh, the Kingdom’s capital and administrative center of Ar-Riyadh Region, lies in the heart of the Najd Plateau in the central part of the country, at an elevation of nearly 600 m above sea level. (Figs. 1, 2) Ar-Riyadh began about three centuries ago as a village on the rains of the city of Ha'iraj, which was the capital of the region of Al-Yamamah and a meeting point for the supply of caravan seeds used in agricultural produce. Ar-Riyadh is now among the fastest growing cities, its area was about one sq km when King Abdulaziz retook it in 1902, and by the year 2003 its developed urban area exceeded 1000 sq km. The population has grown from about 800 in 1911 to more than 4,087,153 inhabitants in 2005. Ar-Riyadh is distinguished by its well-developed infrastructure, which is among the newest on Earth with wide speedways, flyovers, tunnels, parks, government facilities, and malls. Ar-Riyadh contains universities, institutions, research centers, cultural centers, and museums, as well as specialized health services, the largest national and international corporations, embassies and diplomatic missions.
Faulting in Southeastern Khamis Mushait

Metalimentary rocks of volcanic origin, which constitute a part of the Shihran Group, outcrop in the southeastern part of the city of Khamis Mushait in the southwestern part of the Arabian Shield (Fig. 1). These rocks were subjected to tectonic movements that resulted in the formation of two regional faults with their axes oriented to the south and southwest. In some places, they are intruded by younger post-orogenic phanerites, of which the most important are composed of gabbronorites and various granitic compositions. The satellite images, which were enhanced digitally (Figs. 2-4), show that this part of the Arabian Shield was deformed by a right-lateral strike-slip fault system trending east-west over a distance of more than 20 km. The satellite image also illustrates the conjugating relation of these faults with the axial traces of the previously mentioned folds, and the igneous intrusions which correspond to the faults in their orientation. The geologic map (Fig. 5), which was drawn on the basis of these images, shows the relationship between the system of folds, the faults, and the various rock units that make up this part of the Arabian Shield.

Figure 1: A Landsat Thematic Mapper (TM) image above the faults in the southwestern part of Khamis Mushait City.

الصدوع جنوب شرق خميس مشيط

تعرض الصدع النبطي للمنطقة الممتدة من أقصى جنوب غرب السعودية. ركائز صخور النباتات التي تشكل جزءًا من مجموعة شيرابن تظهر في وادي خميس مشيط في الجزء الشرقي الغربي من الصدع. هذه الصخور كانت معرضة لحركات تكتونية تحدث خلال العصر النوري. الصور المزودة بعلامات الصور، والتي تم تعديلها باللمسات الرقمية (الصور 2-4)، تظهر أن هذا الجزء من الصدع تشكله نظام من الصدع الريفي من الفوهة نوريفة. الصور الفوتوغرافية المجهزة برؤية عمياء (الصور 5) توضح العلاقة بين نظام الصدع، الصدع، والجدران العمياء التي تقوم بحفر هذا الجزء من الصدع.
Panoramic 3D View of Ha’il City Area

Remote sensing techniques integrated with Digital Elevation Models (DEM) are used to develop realistic three-dimensional panoramic views of a site. These techniques provide detailed information on the topography of a given area and the relationships between its various landforms.

The panoramic view of the Ha’il area (Fig. 1), produced by merging a SPOT-4 image and the DEM, shows the village of Al-Hufayj in the foreground, surrounded by the sands of Al-Nafud, and beyond them the mountain range of Jabal Aja’. In the background, the town of Ha’il appears in the upper part of the panorama.
Large parts of the Kingdom are covered by sand seas such as Al-Nafud, Al-Bayda, Al-Falaj, and Al-Diriyah. Al-Khay, each of which has different types of sand bodies as crescentic, barchan, parabolic, dune, linear, and star dunes. The predominant types of sand dunes in Al-Nafud are barchanoid, linear, and star dunes. Al-Dakhliya is characterized by linear and crescentic dunes that are composed of yellowish to reddish fine-grained sand, while Al-Jawf is characterized by parallel chains of crescentic sand dunes that are composed of white coarse-grained sand. Al-Ra’sh Al-Khay is made up of linear and crescentic dunes that are composed of reddish fine-grained sand, in some parts the height of mega-barchan dunes reaches up to 200 m above the ground surface. Some other sand bodies such as sand sheets cover the floors of some wadis and flat landsforms.

Remote sensing techniques (Figs. 1, 3) can be utilized to identify the sandy terrains, types of sand dunes, and to monitor and estimate the rate and direction of sand dune movement. Such technology is also useful to determine sand control measures needed to stop or mitigate the sand erosion processes that may pose hazards to urban facilities and transportation projects within sandy desert landsforms.

Figure 3: Landform image of sand dunes in Al-Nafud. A range in the sands of Wadi Al-Diriyah near Al-Dakhla."
Sand and Duststorm

Weather and Climate

The satellite image above shows a duststorm crossing the Arabian Peninsula, moving from Iraq, passing over the Red Sea, and into the western Indian Ocean. The image was acquired by MODIS on 29 May 2001.

Meteosat satellite images are used to identify the conditions that give rise to duststorms and sandstorms, to monitor their development, and to identify the places that are likely to influence them or be affected by them (Figs 1 - 3). Dust storms and sandstorms are among the atmospheric phenomena to which the Kingdom's weather is subject, especially during periods of atmospheric instability resulting from changes in air pressure and the nature and strength of rising air currents. Sandstorms and duststorms differ in the size of the grains they contain, as well as the height that those grains rise above the surface of the earth, and the speed of the winds that give rise to them. Sandstorms cover smaller areas than dust storms and blow at lower heights because of their larger grains. Factors that affect the frequency and severity of these storms include the nature of the land surface, its moisture and plant cover, wind direction, the duration of the gale, and the distance that it blows.
Al-Jubayl Marine Reserve

The Jubayl Marine Wildlife Sanctuary was initiated north of Jubayl Industrial City in 1993 in order to restore the wildlife and marine habitats along the shores of the Arabian Gulf (Figs. 1 and 2). The sanctuary covers more than 2300 sq km, it includes the shallow bays of Dawlod al-Deffah and Dawlod al-Musalmamah and the coral islands of Haraj, Karim, Kuryah, Jada, and Jargal, as well as a coastal strip extending from Abu Ali island to Raf al-Aziz. Along the shores and islands are found mangroves, seagrass, and ducks, as well as migratory seabirds. Thicknesses of black mangroves on Qarn al-Haraj and in Dawlod ad-Deffah serve as nurseries for invertebrate species including shrimp, crabs, and marine mollusks, as well as fishes. Coral reefs make up a suitable environment for crustaceans, many fish species, and sea turtles. Red foxes and rodents also inhabit the sanctuary.

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Al-Jubayl Marine Reserve

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Ar-Riyadh Urban Growth

Remote sensing technology employing a series of successive satellite images helps in defining and monitoring the changes that occur in the urban development of cities over successive periods of time. A comparison of the two satellite images of the city of Ar-Riyadh, taken in the years 1972 and 2001 (Figs. 1 and 2), and the aerial photograph taken in 1950 (Fig. 3), reveals the remarkable expansion and growth that Ar-Riyadh went through during this period, as the surrounding desert lands were progressively settled.

As a result of the economic upswing and improvement in the Kingdom’s standard of living, the area of Ar-Riyadh expanded from about 55 square kilometers in 1950 to 356 square kilometers in 1981, and by 2003, the developed area reached nearly 1000 square kilometers. This urban expansion accompanied the growth of the city’s population, which soared from 82,000 in 1950 to about 700,000 in 1975, and then to more than four million in 2005.

Figure 2 shows the urban fabrics of Ar-Riyadh and its expansion along a number of axes, especially to the north and east, as well as the new residential areas that grew up on the outskirts of the city, and the growth of the network of roadsways that connect the different parts of Ar-Riyadh with one another or with other cities; these axes appear in Figs. 1 and 3.

Also note in figure 2 the development of agricultural activities in the area surrounding Ar-Riyadh, as compared with the extremely limited extent of such activities in figure 1.
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